

KELLY, SEAN MICHAEL, M.A. A Model for Predicting Highway Noise Using a Geographic Information System: Interstate 73 in Guilford County, North Carolina. (2013) Directed by Dr. Rick Bunch. 101 pp.

The purpose of this research is to develop a predictive model for estimating sound levels from a highway traffic source for a future highway. The study area for this research is the future Interstate 73 corridor from North Carolina highway 68 to U.S. Highway 220 in northwest Guilford County, North Carolina.

The model uses a Geographic Information System to produce a raster map with a 10 meter resolution predicting decibel levels within a one mile buffer of the future interstate route. Sound levels are calculated using a Euclidean distance from the interstate in combination with an NLCD data set and a LiDAR derived digital elevation model.

Significant increases in noise levels were predicted for three distinct traffic conditions. Sound levels were estimated to be noticeable from as great a distance of a mile from the proposed highway. As traffic volume is increased, the distance of noticeable noise is increased dramatically.

A MODEL FOR PREDICTING HIGHWAY NOISE USING A GEOGRAPHIC  
INFORMATION SYSTEM: INTERSTATE 73 IN GUILFORD  
COUNTY, NORTH CAROLINA

by

Sean Michael Kelly

A Thesis Submitted to  
the Faculty of The Graduate School at  
The University of North Carolina at Greensboro  
in Partial Fulfillment  
of the Requirements for the Degree  
Master of Arts

Greensboro  
2013

Approved by

---

Committee Chair

## APPOVAL PAGE

This thesis written by SEAN MICHAEL KELLY has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

Committee Chair \_\_\_\_\_

Committee Members \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_  
Date of Acceptance by Committee

\_\_\_\_\_  
Date of Final Oral Examination

## ACKNOWLEDGMENTS

Thank you to Dr. Rick Bunch for his efforts and guidance in developing this research. Thank you to Dr. Roy Stine and Dr. Zhi-Jun Liu for their support of this endeavor. I would like to give an especially big thanks to my children, Thomas, Nathan, Abigail, Bethany, Miriam, Olivia, Caleb, Elianna, and Levi for putting up with the long hours and the time away from home. Finally, a gigantic thank you to my wife, Susan who has always supported me and stood by me on this colossal adventure.

## TABLE OF CONTENTS

	Page
LIST OF TABLES .....	vi
LIST OF FIGURES .....	vii
 CHAPTER	
I. INTRODUCTION .....	1
II. LITERATURE REVIEW .....	12
Traffic Noise Calculation Models.....	12
Mathematical Models.....	17
GIS Models .....	20
TRAEMS Model .....	20
TNoiseGIS Model .....	21
3D Building Model .....	22
DRONE Model .....	23
SPreAD-GIS Model .....	24
FHWA Model .....	25
Impact of Traffic Noise on Property Value .....	26
III. TRAFFIC NOISE PREDICTION MODEL .....	28
Developing an Ambient Noise Model .....	29
Developing a Baseline Traffic Volume for Future Interstate 73 .....	32
Calculating the Source Noise Level.....	34
Modeling Noise Propagation Based on Distance.....	36
Calculating the Effect of Landcover on Sound Level.....	40
Calculating the Effect of Elevation on Sound Level .....	45
IV. MODEL RESULTS .....	49
Results of the Overnight Traffic Model.....	50
Results of the Daytime Traffic Model .....	61
Results of the Heavy Traffic Model.....	71
V. CONCLUSION.....	83
Review of the Results .....	83

Difficulties in Developing This Model .....	85
Assumptions Concerning This Model .....	87
Impact of Highway Noise on Residents and Businesses .....	89
REFERENCES .....	91

## LIST OF TABLES

	Page
Table 1.1. FHWA’s Corridor Description for High Priority Corridor 5 – Interstates 73/74 .....	5
Table 2.1. A Comparison of Principle Traffic Noise Prediction Models (Steele 2001) .....	14
Table 3.1. Classification Values for Vegetation Types .....	41

## LIST OF FIGURES

	Page
Figure 1.1. High Priority Corridors Designated as Future Interstates by Congress (FHWA) .....	4
Figure 1.2. Proposed Interstate 73/74 Alignment, North Carolina (Economic Atlas of North Carolina) .....	7
Figure 1.3. Interstate 73 Alignment Through Guilford County, North Carolina (Economic Atlas of North Carolina) .....	8
Figure 1.4. Major TIP Projects, Guilford County, North Carolina (Greensboro Urban Area Metropolitan Planning Organization) .....	9
Figure 1.5. TIP Project R-2413, NC 68 Connector – US 220 (NCDOT) .....	10
Figure 3.1. Ambient Noise Level – Future Interstate 73 .....	31
Figure 3.2. Sound Level Values Based on Distance from Source .....	39
Figure 3.3. Reclassified Landcover Types .....	43
Figure 3.4. Sound Levels from Interstate 73 Based on Distance from Source and Landcover .....	44
Figure 3.5. Flow Direction Map – Interstate 73 Study Area .....	47
Figure 3.6. Final Sound Level Raster for the Future I73 Corridor .....	48
Figure 4.1. Sound Level Contour Map, Overnight Traffic .....	51
Figure 4.2. Increase in Sound Levels, Overnight Traffic, Interstate 73 .....	54
Figure 4.3. Selected Study Areas, Overnight Traffic .....	56
Figure 4.4. Study Area 1, Overnight Traffic .....	57
Figure 4.5. Study Area 2, Overnight Traffic .....	59
Figure 4.6. Study Area 3, Overnight Traffic .....	60



Figure 4.7. Sound Level Contour Map, Daytime Traffic .....	63
Figure 4.8. Increase in Sound Level, Daytime Traffic, Interstate 73.....	64
Figure 4.9. Difference in Predicted Sound Levels, Overnight and Daytime Traffic .....	66
Figure 4.10. Study Area 1, Daytime Traffic .....	67
Figure 4.11. Study Area 2, Daytime Traffic .....	69
Figure 4.12. Study Area 3, Daytime Traffic .....	70
Figure 4.13. Sound Level Contour Map, Heavy Traffic .....	72
Figure 4.14. Comparative Map of 35 dBA Contours for All Three Models .....	73
Figure 4.15. Increase in Sound Level, Heavy Traffic, Interstate 73 .....	75
Figure 4.16. Difference in Predicted Sound Levels, Overnight and Heavy Traffic .....	76
Figure 4.17. Study Area 1, Heavy Traffic .....	79
Figure 4.18. Study Area 2, Heavy Traffic .....	80
Figure 4.19. Study Area 3, Heavy Traffic .....	82

## **CHAPTER I**

### **INTRODUCTION**

The purpose of this study is to provide a model and methodology for estimating the impact of highway traffic on noise levels within a one mile distance of the 8.4 mile section of Interstate 73 through northwest Guildford County. Estimated highway traffic volumes, landcover and elevation were used as primary datasets for the noise prediction model. These datasets were used to produce a decibel level map of an area within one mile of the future Interstate 73 section.

Just as government agencies conduct environmental impact studies when considering a proposed highway development, this research will analyze the noise impact of the future Interstate 73 development. Landowners will be able to use this research to understand how they will be affected by traffic noise. This will allow them to plan on methods to try to reduce the impact of the traffic noise before they experience it. Developers will be able to use this information to better plan both residential and commercial developments along this new highway, taking into account noise levels. Finally, state government, while not being obligated to construct noise barriers, could use the results of this study to identify areas which will be greatly impacted by traffic noise, which could lead to governmental action, such as erecting noise barriers in crucial areas.

One of the most impressive endeavors in transportation in the United States has been the development of the Interstate Highway system. The vision for what has become our current system of multilane divided, access fully-controlled highways began with Dwight D. Eisenhower. In 1919 Eisenhower participated in a military convoy across the United States from Washington, DC to San Francisco, CA. This convoy took 62 days, experiencing many obstacles such as break downs, muddy roads causing vehicle to get stuck, wooden bridges unable to support the weight of the vehicles and adverse weather conditions made worse by the poor condition of the roads (Weingroff, 1996).

When Eisenhower was serving in Europe during World War II, he was impressed with the efficiency and engineering of the German Autobahns. He remembered his past experience in 1919 and began to have a vision of a system of highways in the United States similar to the German Autobahns.

In 1953, when Eisenhower took office, one of his top priorities was the development of a nationwide highway system. In 1954, Eisenhower signed the Federal Highway Act which was the first step toward a system of highways. This bill authorized \$175 million toward the construction of an interstate highway system. Eisenhower eventually signed the 1956 Federal Highway Act which set the standards for the system that the nation has today. These standards included four lane access fully controlled highways with no at-grade interchanges, no businesses on interstate right of ways and mandatory speed limits and engineering design standards (Weigroff, 1996).

Since then, Interstate Highway construction has continued. Construction began on a section of Interstate 40 in St. Charles County, Missouri on August 13, 1956. Of the

originally planned routes, only a section of Interstate 95 in New Jersey, north of Philadelphia has yet to be completed. However, several routes have been added to the original plan. One of these routes is Interstate 73, which is planned to go from Myrtle Beach, SC to Saute Sainte Marie, MI.

The Interstate 73 corridor was first designated by the Intermodal Surface Efficiency Act of 1991 (ISTEA). It was designated as a high priority corridor. The major advantage of being designated as a high priority corridor is that some of these corridors, including the Interstate 73 corridor, received federal funding through ISTEA and subsequently through TEA-21 and SAFETEA-LU. According to the Federal Highway Administration (FHWA) website, “Section 1105(e) of the ISTEA, as amended, designates all or portions of fourteen high priority corridors as future parts of the Interstate system and authorizes the Secretary to add segments of the corridors to the Interstate System when certain criteria are met.” (FHWA). The Interstate 73 corridor is designated as a future interstate corridor. See figure 1.1 for highways which are designated as High Priority Corridors. See table 1.1 for a description of High Priority Corridor 5.



Figure 1.1. High Priority Corridors Designated as Future Interstates by Congress (FHWA)

Table 1.1. FHWA's Corridor Description for High Priority Corridor 5 – Interstates  
73/74

High Priority Corridor 5:

I-73/74 North-South Corridor from Charleston, South Carolina, through Winston-Salem, North Carolina, to Portsmouth, Ohio, to Cincinnati, Ohio, to termini at Detroit, Michigan and Sault Ste. Marie, Michigan. The Sault Ste. Marie terminus shall be reached via a corridor connecting Adrian, Jackson, Lansing, Mount Pleasant, and Grayling, Michigan.

- i. In the Commonwealth of Virginia, the Corridor shall generally follow--
  - I. United States Route 220 from the Virginia-North Carolina border to I-581 south of Roanoke;
  - II. 581 to I-81 in the vicinity of Roanoke;
  - III. I-81 to the proposed highway to demonstrate intelligent transportation systems authorized by item 29 of the table in section 1107(b) in the vicinity of Christiansburg to United States Route 460 in the vicinity of Blacksburg; and
  - IV. United States Route 460 to the West Virginia State line.
- ii. In the States of West Virginia, Kentucky, and Ohio, the Corridor shall generally follow--
  - I. United States Route 460 from the West Virginia State line to United States Route 52 at Bluefield, West Virginia; and
  - II. United States Route 52 to United States Route 23 at Portsmouth, Ohio.
- iii. In the States of North Carolina and South Carolina, the Corridor shall generally follow:
  - I. in the case of I-73--
    - A. United States Route 220 from the Virginia State line to State Route 68 in the vicinity of Greensboro;
    - B. State Route 68 to I-40;
    - C. I-40 to United States Route 220 in Greensboro;
    - D. United States Route 220 to United States Route 1 near Rockingham;
    - E. United States Route 1 to the South Carolina State line; and
    - F. South Carolina State line to the Myrtle Beach Conway region to Georgetown, South Carolina, including a connection to Andrews following the route 41 corridor and to Camden following the U.S. Route 521 corridor; and
  - II. in the case of I-74--
    - A. I-77 from Bluefield, West Virginia, to the junction of I-77 and the United States Route 52 connector in Surry County, North Carolina;
    - B. the I-77/United States Route 52 connector to United States Route 52 south of Mount Airy, North Carolina;
    - C. United States Route 52 to United States Route 311 in Winston-Salem, North Carolina;
    - D. United States Route 311 to United States Route 220 in the vicinity of Randleman, North Carolina;
    - E. United States Route 220 to United States Route 74 near Rockingham;
    - F. United States Route 74 to United States Route 76 near Whiteville;
    - G. United States Route 74/76 to the South Carolina State line in Brunswick County; and
    - H. South Carolina State line to the Myrtle Beach Conway region to Georgetown, South Carolina.

- "Statutory Listing of Corridor Descriptions" - FHWA

In North Carolina, Interstate 73 is designated to run from US Route 1 near the South Carolina State line to US route 220 at the Virginia State line (figure 1.2). Currently only a few sections of Interstate 73 are completed to interstate standards. These sections include the Greensboro Urban Loop section from Bryan Blvd to the US 220 exit at Interstate 85, along the US 220 corridor from Ulah to Ellerbe and the Rockingham bypass near US 74.

Often referred to as the US 220 connector, the Interstate 73 corridor has an accepted route which will travel through northwest Guilford County, North Carolina (Figure 1.3). Referred to as Transportation Improvement Project (TIP) R-2413 by the North Carolina Department of Transportation (NCDOT), this section of I-73 is projected to begin construction in 2014. The estimated cost from 2008 is over \$190 million (Metropolitan Planning Organization, 2008). See figure 1.4 for TIP projects in Guilford County.

The route which I-73 will follow through Guilford County will take it through the growing communities of Oak Ridge and Summerfield. This stretch of Interstate 73 will be an 8.4 mile new construction from NC highway 68 near the Piedmont-Triad International Airport to US highway 220 north of Greensboro (Figure 1.5). This section of the project will relocate 15 residential properties and 5 businesses. Purchasing of right of way began in 2011.

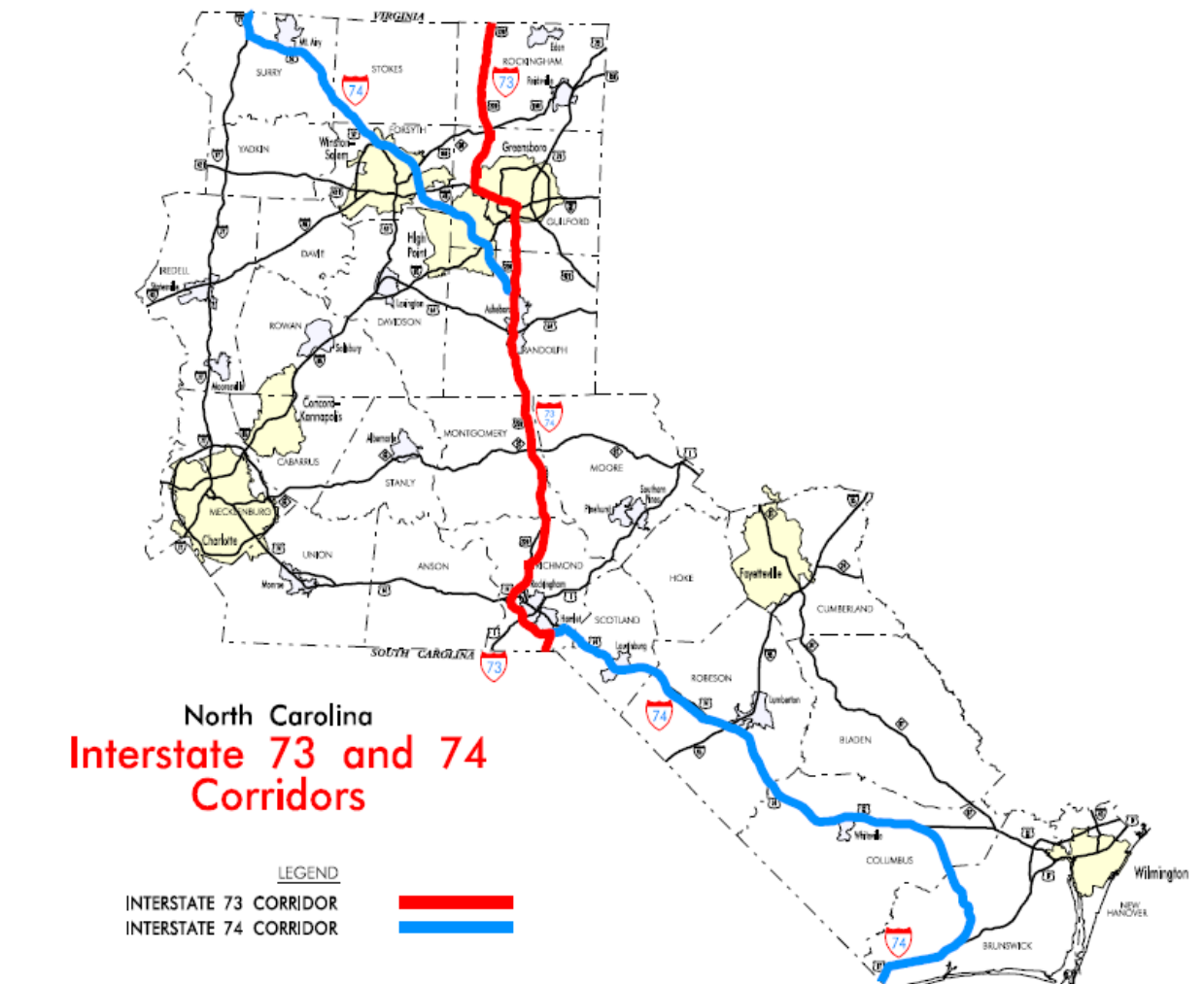


Figure 1.2. Proposed Interstates 73/74 Alignment, North Carolina (Economic Atlas of North Carolina)



# Guilford County

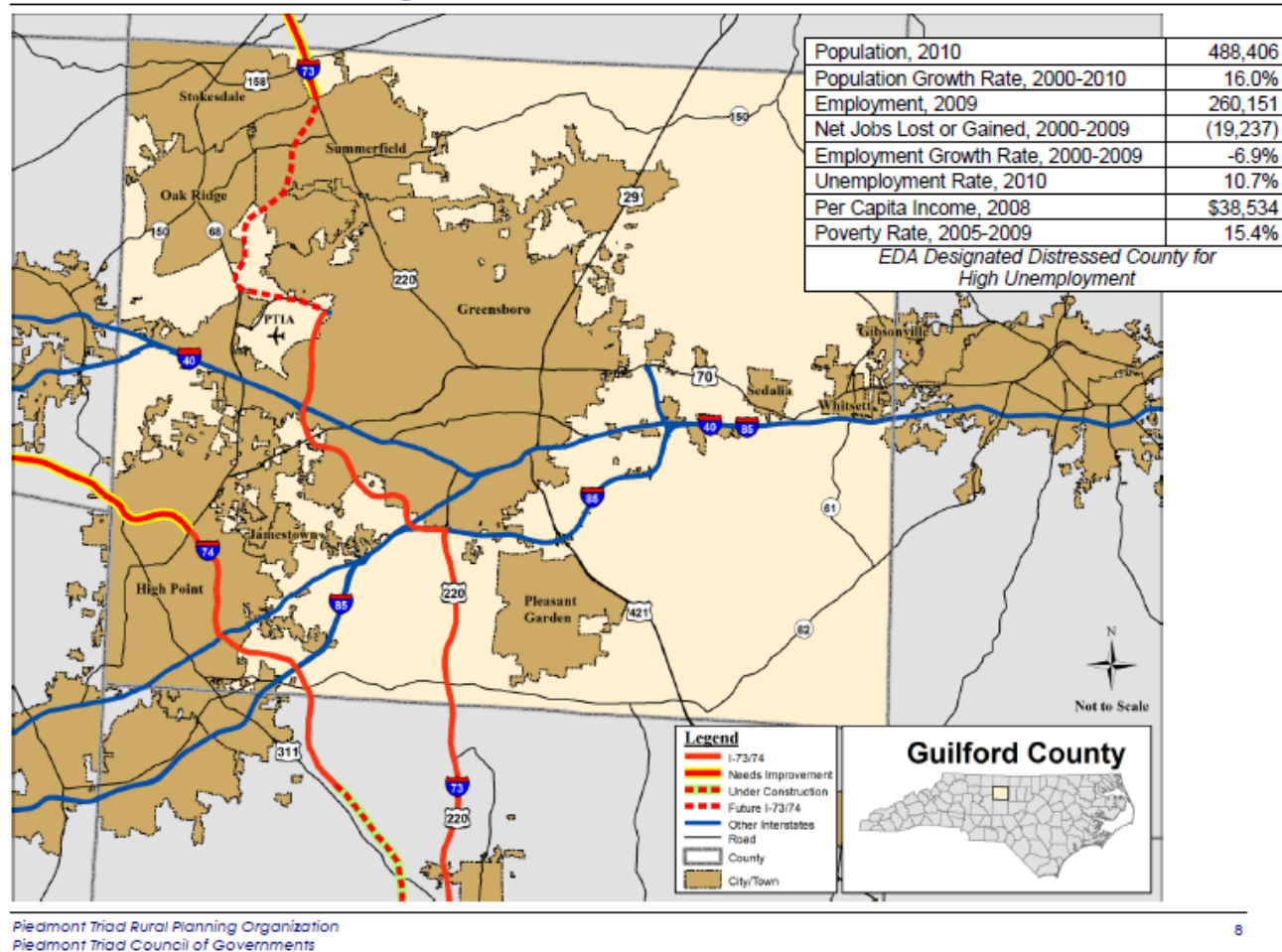


Figure 1.3. Interstate 73 Alignment through Guilford County, North Carolina (Economic Atlas of North Carolina)

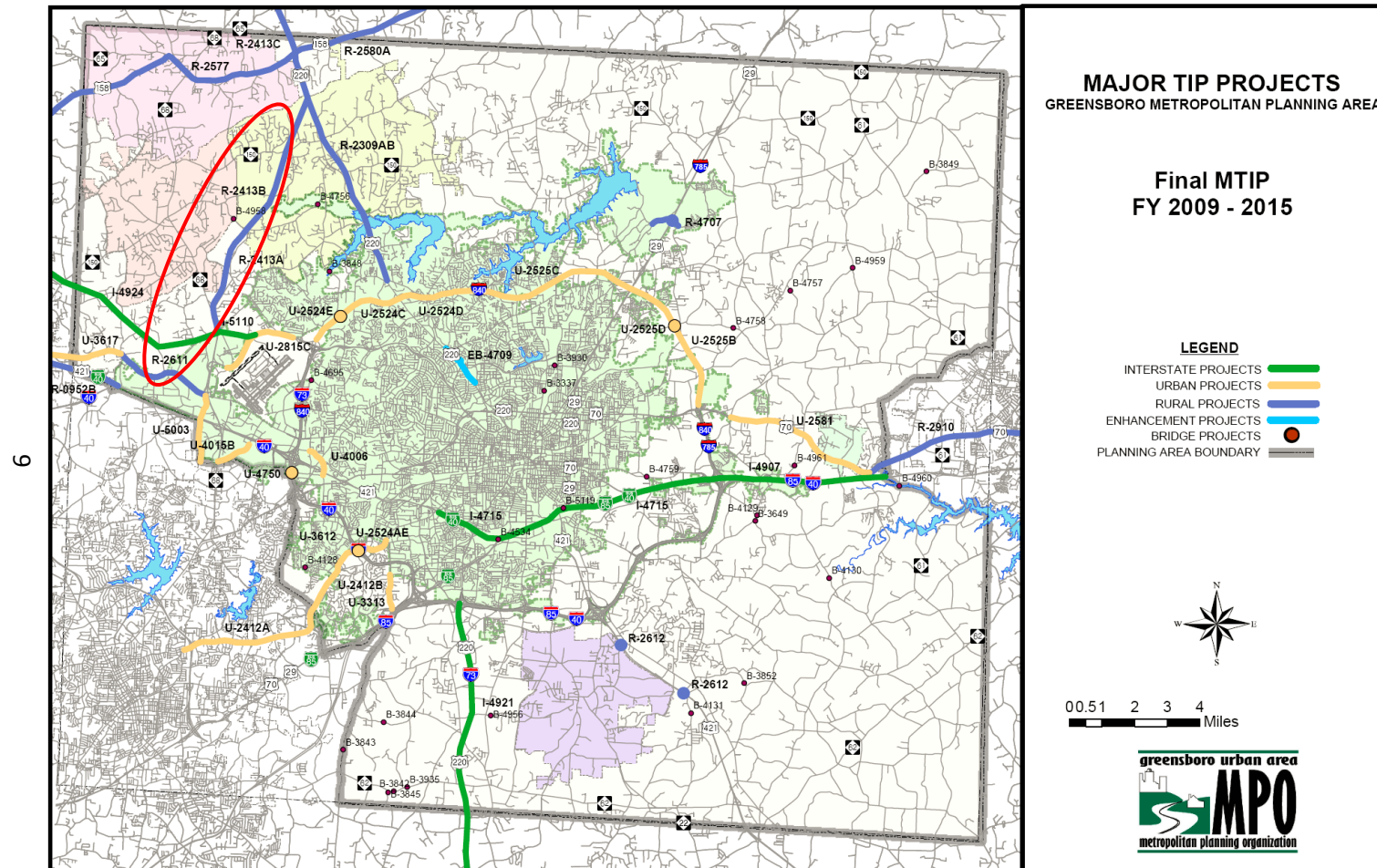


Figure 1.4. Major TIP Projects, Guilford County, North Carolina (Greensboro Urban Area Metropolitan Planning Organization).

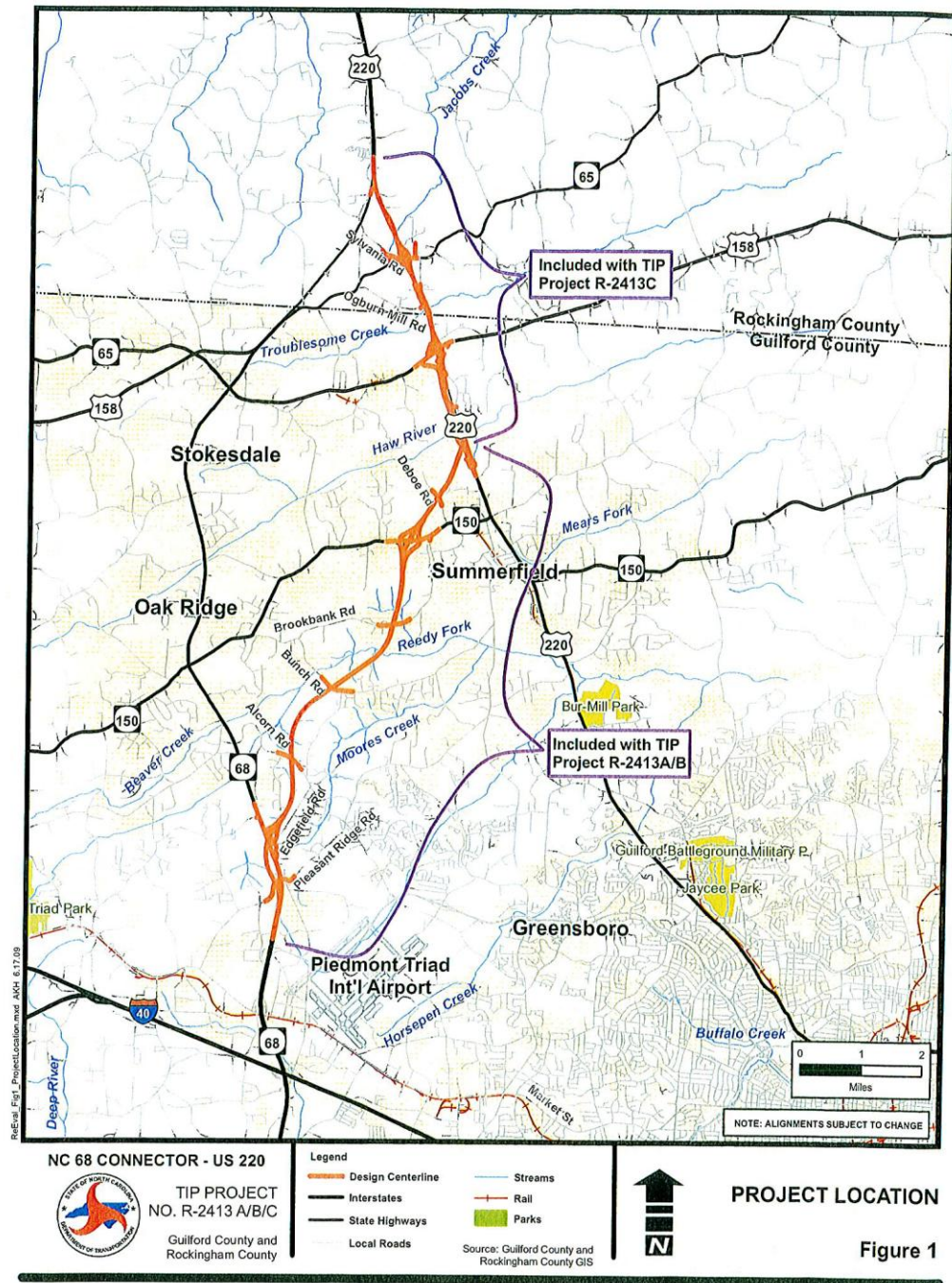


Figure 1.5. TIP Project R-2413, NC 68 Connector – US 220 (NCDOT)



The section of Interstate 73 to be built will meet federal interstate standards. The typical section of the project will include 4 lanes of traffic (two in each direction) and a 46 foot grassy median. The minimum right of way will be 175 feet but could be larger in certain sections depending upon alignment and roadway conditions (NCDOT).

The problem with developing any new highway is the impact it will have on those who reside and work within the area affected by the construction. Many issues arise as new highways are proposed, constructed and opened for use. First, there are those who are affected because their property lies within the right of way of the new highway and must be purchased for use by the state. Another issue is the environmental impact of the new highway development, especially on watersheds and natural habitats. A third issue, on which this study focused, is how building a new highway indirectly affects those who are in near proximity to that construction.

This study examines the impact of highway traffic on noise levels within one mile of the proposed construction of Interstate 73 from the junction of North Carolina Highway 68 to the junction of U.S. Highway 220 in Guildford County, NC. According to the Town of Summerfield, “Under federal and state law, development that has occurred since public notice of the facility are not eligible for noise barriers and other mitigation efforts” ([www.summerfieldgov.com](http://www.summerfieldgov.com)). Because of this, the impact of highway traffic noise on nearby residents could be substantial.

## **CHAPTER II**

### **LITERATURE REVIEW**

Noise propagation as it relates to traffic volume has been the subject of a number of studies. Various approaches have been taken to examine how traffic impacts the transmission of noise in adjacent areas. Some models deal more with the calculation of traffic noise as it relates to the volume of traffic. Other models have looked at how spatial features influenced traffic noise impacts locations. Several studies have also examined how barriers, such as building impact noise.

#### *Traffic Noise Calculation Models*

Some models have been used to develop formulas for calculating the propagation of traffic noise. These models are mathematically complex but they do an excellent job of predicting noise levels.

Steele (2001) gives a history of various traffic noise prediction models. He points out the fact that traffic noise prediction models were developed as early as the 1950s and 1960s. However these models provided limited analytical capabilities and only considered single vehicles travelling at a constant speed (Steele 2001). An early model was developed and illustrated in the 1952 *Handbook of Acoustic Noise Control*. It assumed speeds of 35-45 miles per hour and was calculated for distances of greater than 20 feet. Other early models were derived to improve upon the 1952 version, including a model developed by Nickson and Lamure in 1965.

Steele goes on to discuss more recent models. He argues that most of these models assume a point source, although there are a few which have their origin as a line source (Steele 2001). He gives six common models that he argues are used in modern traffic noise prediction models. These models are summed up in table 2.1. Steele also discusses various strength and weaknesses of these models.

Since this study focused on the construction of an Interstate highway, the model that is most relevant to this study is the FHWA TNM model. This model is widely accepted within the traffic engineering industry and used frequently by the government of the United States. The FHWA TNM model will be discussed in detail later in the chapter. Steele seems to appreciate this model among the six models he examined. He states, “The FHWA TNM model is an example of the trends toward more accurate physics in models and toward more realistic representation of actual traffic flows” (Steele 2001). Steele argues that the FHWA TNM model is one of the more accurate models available. Its weaknesses are that it does not provide a comprehensive sound propagation predictions and it does not incorporate traffic interruptions.

One other model that Steele examines is the CoRTN model. This model was developed by the United Kingdom for the purpose of aiding road design. Steele claims that this model assumes a line source and constant traffic speeds and therefore under estimates high levels and overestimated low levels of traffic noise (Steele 2001).

Table 2.1. A Comparison of Principle Traffic Noise Prediction Models (Steele 2001)

A Comparison of Principle Traffic Noise Prediction Models								
	FHWA STAMINA	FHWA TNM 1.0	01 db MITHRA	CoRTN	RLS 90	STL-86	ASJ-1993	Ideal Model
Government al Users	USA, Canada, Japan, Mexico	In course of Preparation	France, Belgium	UK, Austrailia, Hong Kong, New Zealand	Germany	Switzerland	Japan	Not Applicable
Applications	Highway ( $L_{eq}$ ) not architectural. Grid. Road networks.	Highway ( $L_{eq}$ ), not architectural. Grid, excellent source base. Road networks.	Highways and railways ( $L_{eq}$ ), not architectural. Grid. Good propagation. Simple streams.	Highways (quasi $L_{eq}$ ). Point. Single traffic stream only.	Highways and car parks ( $L_{eq}$ ). not architectural. Point. Good propagation. Simple streams only.	Highways and trams, light rail ( $L_{eq}$ ) not architectural. Point. Simple streams only.	Highway barriers.	Highways ( $L_{eq}$ ) and architectural ( $L_N$ ). Grid. Good propagation. Excellent source base. Complex road networks. All flow conditions.
Predicts traffic volumes?	No	No	Yes	No	Yes	Yes	No	No
Traffic conditions	Constant speed, Grades	Constant speed, acceleration, grades and interruption.	Constant speeds, grades.	Constant speeds, grades	Constant speeds, grades, quasi-intersections, interruptions	Constant speeds, grades	Constant speeds	Constant speeds, grades, accelerations and all types of interruptions and speed changes.
Input Data	Traffic Speed, flow, road and environs data, local characteristics	Traffic type, flow, speed, whether interrupted, road and environs data. Local characteristics	Traffic type, flow, road and environs data.	Heavy/light ratio, flow, speed, road and environs data.	Traffic, type, flow, park or road data, and environs	Traffic type, flow, road and environs data.	Traffic type, flow, speed, barrier geometry.	Traffic type, traffic stream contours, interruption and speed cycles. Local characteristics.
Type	Hybrid, consistent/inconsistent.	Mathematical/hybrid.	Hybrid, consistent	Hybrid, inconsistent	Hybrid, consistent	Hybrid, inconsistent	Mathematical	Mathematical.
Noise descriptor	$L_{eq}$ , quasi $L_{40}$	$L_{eq}$	$L_{eq}$ (8-20 H)	Quasi – $L_{40}$ (18 H)	$L_{eq}$	$L_{eq}$	$L_{eq}$ , quasi- $L_{50}$	$L_{eq}$ and $L_N$ , $N = 1, \dots, 99$ , $L_{max}$ , chosen period
Type of mapping	Point → grid	Multiple dual points → grid	Line → grid	Line → point	Line → point	Line → point	Multiple points → point	Multiple dual points → multigrid

A Comparison of Principle Traffic Noise Prediction Models								
	FHWA STAMINA	FHWA TNM 1.0	01 db MITHRA	CoRTN	RLS 90	STL-86	ASJ-1993	Ideal Model
Source	Simple streams	Simple streams	Simple streams	Single Stream	Simple stream	Simple stream	Simple straight stream	Multi-stream, branched and interlocked streams
Propagation	Energy type	Energy Type	Ray tracing	Energy by type	Energy type	Energy type	Mathematical (Velocity potential)	Optional
Vehicle types	Automobile/medium trucks/heavy trucks	Optional spectra for automobiles/medium trucks/heavy trucks/busses/motorcycles	Light Vehicles, heavy vehicles and trains	Light vehicles/heavy vehicles	Light vehicles/heavy vehicles/ car parks	Light vehicles/heavy vehicles/trams and suburban trains on roadways	Light vehicles/medium vehicles/heavy vehicles	User selection from library or local data
Validation	Contingent; 0.58 to -1.3 dBA @ 15m to 60 m	Not readily available	Not readily available	+1.4 @ 50 to 54.9 dBA (Delany): -1.2 @ 80 to 84.9 dBA. +1.7 @ facades (Saunders)	Not readily available	Not readily available	Not readily available	Not applicable
Weighting: Source/receiver	dB(A)/dB(A)	1/3 octave/dB(A)	Octave/dB(A)	dB(A)/dB(A)	dB(A)/dB(A)	dB(A)/dB(A)	dB(A)/dB(A)	Octave/dB(A)
Major Faults	No $L_N$ , no interruptions	No $L_N$ , simple interruptions only.	No $L_N$ , no interruptions, no local characteristics	No $L_{eq}$ , $L_{40}$ not rigorous, no interruptions, single traffic streams only, no local.	No $L_N$ , simple interruptions only, no local characteristics	No $L_N$ , simple interruptions only, no local characteristics	No $L_N$ restricted to quasi $L_{50}$ , no interruptions, long roadside barriers only	None
Author's opinion	Obsolete	$L_{eq}$ only; allows local vehicle types, accurate	Use for complex buildings and unknown traffic flows	Obsolete	Use for car parks and unknown traffic flows	Use for trams and light rails and unknown traffic flow	Use for free-flowing traffic with long roadside barriers	$L_{eq}$ , $L_N$ , $L_{max}$ , $L_{min}$ general purpose and architectural; allows local vehicle types. Accurate.



Steele does say that this model is suitable for a long line of free flowing rush hour traffic or trains at a distance from the observer, but is not suitable at close distances or when vehicle spacing is very even or uneven (Steele 2001).

Another study that examined noise propagation models was developed by DeKluijver and Stoter (2000). The authors presented a paper for the 29<sup>th</sup> International Congress and Exhibition on Noise Control Engineering which dealt with the topic of standardizing and quantifying the results of noise studies. Their paper did not examine any particular model for noise propagation, but made several suggestions for various models that are used in Europe. These suggestions could apply worldwide, as many countries are using highly differing models for noise propagation. Two suggestions that were made seem to be valid for all noise models. First, they suggested that models should start with the same background data in order to be able to accurately compare results from region to region. Second, they suggested that all studies use the same mathematical model for predicting noise. Their focus is mainly on standardizing processes for Europe.

As various models were researched for this study, it was noticed that these same issues plague most research in the topic of traffic noise. No two models begin with the same data and like many models designed for Europe, each model uses a different method for calculating noise propagation. The main reason for the lack of ubiquity among noise propagation methods is because many of the models are developed from site sample measurements which make them less accurate in other regions with different geography. This makes it difficult for someone to not only design an accurate model for

predicting noise propagation, but it also places additional burden on the user to make decisions about which data are most important.

### *Mathematical Models*

Tansatcha, et al. (2005) developed a perpendicular noise propagation model to be used for a variety of vehicles and configurations of highways. By using the centerline of the highway and calculating the effect of traffic noise perpendicular to the centerline, they were able to develop a goodness-of-fit model that could be used to calculate the effects of traffic on noise in future construction of highways in Thailand.

Tansatcha developed an empirical model using a noise level meter and by spot testing noise levels at a distance of 15m from the roadway. They classified different types of vehicles into eight types: automobile, light truck, medium truck, heavy truck, semi-trailer, full trailer, bus and motorcycle (Tansatcha, et. al. 2005). They calculated the noise generated by the individual vehicle over a 10 second period. They used 34 collection sites over a distance of 22 km. Using a linear regression, they developed a basic noise model for each type of vehicle.

Because Tansatcha (2005) developed his noise model for a period of 10 seconds and because most standard noise models the prediction index is over a one hour period, Tansatcha (2005) had to convert his model to represent this one hour period.

Tansatcha's (2005) model has several advantages and several disadvantages. First of all, because this model uses differing vehicle types to predict traffic noise, it seems to be a fairly accurate model for predicting traffic noise, given the right assumption of the number of vehicles which will be using the highway in the future. A

second advantage is that this model takes into account the number of lanes, frontage roads, medians, and right of ways associated with the highway. This helps to give a realistic prediction of the actual traffic which will be associated with this road. A third advantage is that the model also takes into account the speed of the traffic.

One of the disadvantages is that it is strictly a mathematical model and is not specifically designed to deal with geographic space and features. With this model a researcher could go to an individual point on a highway and predict the noise impact from the traffic, but it would be very difficult to predict the noise impact from every point in a 20 mile highway. Also this model does not explicitly take into account physical features, such as topology, land cover, elevation, etc. These real world features will have an effect on how noise is propagated. The equation developed from the sample noise levels is not well suited to predict noise in other dissimilar regions.

A second model created by Golmohammadi, et. al.,(2009) developed what they have termed “a compact model” for noise prediction (Golmohammadi, et. al. 2009). The authors have suggested that there are 12 factors which explain traffic noise levels, 4 types of road dimensions, 4 types of vehicles and 4 traffic speed factors. In the development of their model they used four road dimensions and 3 variables for traffic flow (Golmohammadi, et. al. 2009). Using a microphone set at 3 m from the roadway, they set up 94 stations which to collect traffic noise information. Using the sample noise level data they developed an empirical model to predict traffic noise.

The model does a good job of simplifying the data needed to predict highway noise. The authors state that when testing their model in 48 samples, the difference

between the mean predicted noise level and the actual measurement value was -0.42 dB(A), which indicates a fairly accurate prediction (Golmohammadi, et. al. 2009).

This model has some limitations when applied to a continuous spatial application. First of all this is another mathematical model and not a GIS model. While this works well for spot point prediction of traffic noise, this does not give a continual view of how traffic affects noise along a large portion of a highway. It does not include the physical factors which affect highway noise, such as landcover and slope. The equation developed from the sample noise levels is not well suited to predict noise in other dissimilar regions.

Another model was developed by Li et al (2002). They developed a mathematical model that can be translated to fit the underlying architecture of a GIS. This model incorporates several factors into predicting noise propagation. These factors include speed, traffic flow, distance, finite length of road, ground absorption, surface gradient and shielding (Li, et. al. 2002). This model, according to the authors is based somewhat on the FHWA model which is discussed later in this chapter. This model is developed for a specific static point of reference. It is a complex model with many factors and many complex formulas.

This model is very strong in capturing the technical aspects of noise prediction. Great detail is put into developing the formulas for calculating each of these factors that are then added together to give a decibel result. However, for this reason, this model works better for a small distinct section of road, as compared to a large section of highway, such as the segment of Interstate 73 considered in this study. Also like many

other models that have been considered in this chapter, this model focuses mainly on the urban environment, and does not consider landscape which is an important factor in this study.

### *GIS Models*

This section will provide some of the strengths and weakness for several of the major models that have been developed to leverage the underlying architecture of a GIS.

#### *TRAEMS Model*

Brown and Affum (2002) developed a GIS model called TRAEMS (Transport planning Add-on Environmental Modeling System). This model was designed to be used as an add-on to MapInfo GIS (Brown and Affum 2002). The model was designed for individuals who conduct transportation research and planning. The model addresses several environmental factors such as traffic noise, air pollution, fuel/greenhouse gases and storm water runoff (Brown and Affum 2002).

TRAEMS is based on a British traffic noise model called CoRTN to predict traffic noise. The model takes into account several factors, such as traffic volume, speed, vehicle type, gradient, road surface, distance, ground cover, angle of view, barriers and reflection off of structures on the opposite side of the road.

One of the strengths of this model is that it can be used to analyze data over an entire traffic network and not just along the highways. An additional strength is that it will predict several environmental consequences to a proposed road network and not just traffic noise.

A main weakness is that it is complex and there are other models which used the CoRTN model for predicting traffic noise that are much easier to use, because they do not deal with a myriad of environmental factors. The model is also designed mainly for an urban environment and not for the suburban/rural environment examined in this research.

#### *TNoiseGIS Model*

Pamanikabud and Tansatcha developed and implemented a model using a beta version of software called Traffic Noise Forecasting Model in GIS or TNoiseGIS (Pamanikabud and Tansatcha 2003). This software model integrates one of two noise calculation models: the United Kingdom's CoRTN model and the United States' FHWA.

Road way data are incorporated into the GIS as the base map for analysis. The barrier data, mainly building footprints, are also added into the GIS portion of the model. These barrier data are subsequently used to predict noise propagation around obstacles.

For the FHWA model, data such as highway width, median width, vehicles per hour and speed of vehicles for types of cars, medium trucks and heavy truck are incorporated into the model. For the CoRTN model, attributes such as highway width, median width, total vehicles, percent heavy vehicles, traffic speed gradient and road surface are used in the model. The TNoiseGIS module runs the noise prediction model using the highway attributes with the base map attributes and geometry. Spatial Analyst is then used to analyze and display the data within the GIS platform.

Using the TNoiseGIS model, the researcher can find traffic noise levels at any point or set of points in the study area. The data can also be presented to the researcher

using a grid method or even as a series of contour lines, which can be set at varying intervals, such as 1, 2, 5 or more dBA.

The TNoiseGIS model is well suited for displaying traffic noise, and is useful for studying a large section of highway as opposed to a single point analysis. The model also takes into account buildings and other man-made barriers. However, it does not take into account physical features, such as land cover or elevation and slope in predicting highway noise levels.

### *3D Building Model*

Pamanikabud and Tansatcha (2009) developed a 3-Dimensional (3D) model based on GIS to predict the effect of buildings on traffic noise. Using a previous study, the traffic data were analyzed in a GIS. This model used grid centroids and building structures to predict highway noise. Pamanikabud and Tansatcha (2009) first plotted noise contour lines. An analysis of the sound patterns was then calculated in a 2D format using building footprints.

Pamanikabud and Tansatcha (2009) also automated the noise prediction formulas using programming scripts in a GIS. Pamanikabud and Tansatcha (2009) incorporated the road data and building data into the GIS and calculated the traffic noise level.

Pamanikabud and Tansatcha's (2009) model has several strengths. First, it uses GIS to perform a temporal analysis of traffic noise as opposed to one point in time. The model also takes into account the effect of buildings upon traffic noise. This makes this model useful in real world applications, since most major highways are in place to move

people and goods between centers of population and through build up areas. The model also takes into account, type of traffic, speed of traffic and highway configuration.

However, this model also only considers building footprints which is only one of many features that influences traffic noise. While doing an excellent job on predicting how buildings affect noise propagation, this model does not address other important attenuation variables such as land cover, slope, elevation or other physical features.

#### *DRONE Model*

Chung, et. al. (2007) developed a traffic noise model that integrates time dependant traffic characteristics, such as stop and go traffic, with noise prediction models and has linked it with GIS to provide visual representation. This model, called DRONE (area-wide Dynamic Road traffic Noise) estimates area-wide noise on a whole network of traffic (Chung, et. al. 2007). The model also takes into consideration the build-up of buildings and how the noise levels will be impacted by it.

Chung, et al. (2007) applied this model to a section of Tsukuba city, Japan. The output of the model is a contour map separated by 5 dBA intervals showing how traffic impacts noise levels in this area. The model was used to simulate traffic flow patterns from 7 AM to 9 AM, accounting for congestion and stop and go traffic. The model incorporated formulas to predict noise levels generated from vehicles accelerating, decelerating, idling and moving at a constant speed.

This model's strength is that instead of using one mean speed for traffic, it takes into consideration normal urban traffic patterns which involve vehicles moving (or not moving) at various speeds. This model is especially good for built up urban applications



where terrain and land cover will be less of a factor and, since it accounts for buildings, works best in dense urban areas. This model would be less useful for considering noise prediction for a suburban or rural highway in which traffic speeds are consistent and natural physical features would play a greater role in predicting the noise levels from highway traffic.

#### *SPreAD-GIS Model*

Reed, et. al. (2010) developed a traffic noise prediction model using GIS which considers distance from the source of the sound, ground absorption, atmospheric absorption based on elevation, air temperature and humidity, terrain features and land cover. This was accomplished by developing a software package that is tightly coupled with ArcGIS. The software package is called the System for the Prediction of Acoustic Detectability (SPreAD ) and is a tool that is added to ArcGIS toolbox (Reed, et. al. 2010).

The SPreAD model can be run from single or multiple point sound sources. Because of errors caused by the terrain model, SPreAD is not able to calculate noise levels from line or polygon sources. SPreAD is considered a static model, because it takes a “snapshot” based on conditions at a single point in time (Reed, 9). SPreAD is able to display the results of the model in multiple ways, including a raster output, giving the differing decibel output or a series of contour lines.

This model seems to be one of the best for predicting noise using data from many of the physical features that attenuates the propagation of noise. This model is useful because it does include land cover, elevation, slope and a variety of other factors which

would change the affect of noise experienced as an observer moves away from the noise source.

There are a couple of weaknesses to this model (Reed, et. al. 2010). First, for building a model in which a large continuous portion of highway is analyzed, it would be difficult to use SPreAD to develop a suitable model, due to the fact that using a line source of noise is not available. Second, SPreAD does not seem to account for the influence buildings, which, as noted by other researchers, have an effect on how noise is propagated. However, this application was developed in 2010 and it is quite possible that some of these issues may have since been rectified.

#### *FHWA Model*

The Federal Highway Administration (FHWA) has also developed a model to predict highway traffic noise through the development of software called the FHWA Traffic Noise Model (TNM). It is available to download from the FHWA website for free ([www.fhwa.dot.gov/environment/noise/traffic\\_noise\\_model/purchasing\\_tnm/](http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/purchasing_tnm/)). The 2.5 rollout is the latest available version of the software.

The TNM accounts for various types of vehicles and the noise that they would create. There are five types of vehicles accounted for: automobiles, medium trucks, heavy trucks, busses and motorcycles. The model factors in how noise is impacted by four different pavement types: dense-graded asphaltic concrete (DGAC), Portland cement concrete (PCC), open-graded asphaltic concrete (OGAC), and a composite pavement type consisting of data for DGAC and PCC. TNM also takes into account various road features such as stop signs, toll booths, traffic signals and on-ramp start points.

The FWHA TNM model adjusts the sound levels based on several environmental factors. These include atmospheric absorption, divergence, intervening ground which takes into account ground acoustical characteristics and topography, intervening barriers including walls and berms, intervening rows and buildings and intervening areas of heavy vegetation.

#### *Impact of Traffic Noise on Property Value*

One concern which is perhaps a major problem for homeowners who find themselves located near a proposed highway development is how will the increased noise from a future highway affect their investment in their home, namely their property value. El-Gohary performed a study on how traffic noise impacted property value in the metropolitan Portland, OR area.

El-Gohary (2004) collected data dealing with noise levels along interstate 5 in Portland, OR along with data for properties for the city of Portland. The property data included the market value, total square footage, building square footage, number of bedrooms, number of bathrooms, total number of other rooms, garage capacity, number of fireplaces, age of the property, noise level around the property and distance from the freeway (El-Gohary 2004). The data were analyzed using a stepwise regression to show if noise levels from interstate 5 had any impact on property values, based on similarities in the statistics concerning different types of properties.

El-Gohary (2004) concluded that the nearby freeway had a statistically significant affect on the property values of the properties studied (El-Gohary 2004). He concluded that 70% of the difference in comparable properties market value can be attributed to

traffic noise. His recommendation to the city of Portland is to erect sound barriers along interstate 5 to try and reduce some of the traffic noise in nearby properties.

### **CHAPTER III**

#### **TRAFFIC NOISE PREDICTION MODEL**

A model was developed to predict the amount of traffic noise generated by vehicles travelling on the future section of Interstate 73. Three models were used to evaluate the noise levels based on different traffic conditions. A low noise model was based on overnight traffic. The assumption here is that overnight traffic should consist of small amounts of light vehicles (e.g. cars) but large amounts of heavy vehicles (e.g. semi-trucks). A second model was created to examine moderate traffic levels consisting of a mix of light and heavy vehicles during normal daytime hours. A final model was developed to consider a rush hour scenario. This model included a mix of light and heavy vehicles, as with the second model, but with a greater volume. A formula for predicting noise based on vehicle type was used to set the initial decibel level.

In order to input these data into the model, several different datasets were gathered. To begin with, a dataset containing the proposed alignment of the Interstate 73 corridor was obtained. This was downloaded from the Guilford County GIS website under the FTP data as a shapefile. This dataset included section of Interstate 73 used in this study was selected and saved to a separate shapefile.

The Interstate 73 layer was buffered (one mile) to create the study area for this research. The one mile buffer was based on research conducted by numerous research studies that concluded that traffic noise at a distance of greater than 500 m (1640 feet or

less than 1/3 mile) is negligible. This assures that all affected areas of the study are recognized.

A Digital Elevation Model (DEM) at a spatial resolution of 10 m was acquired to provide topographic data for the model. This DEM was derived from Light Detection and Ranging (LiDAR) data from the region. A 2006 landcover dataset was used to determine areas of heavy vegetation. Both of these were obtained from NCOneMap, which is a state government website that provides freely available geographic data. Both files were clipped to the size of the study area from the buffered Interstate 73 file.

The building footprint data were gathered from the Guilford County GIS webpage. These were clipped to the size of the study area. These data were then converted to a raster format, at a 10 m spatial resolution, and the final sound levels were joined to these data.

Using the Interstate 73 footprint, landcover and elevation data, these noise models were developed based on differing traffic volumes. The data were analyzed for affected properties to predict how much they will be affected by the traffic noise from the new highway.

#### *Developing an Ambient Noise Model*

The first step in analyzing the impact of traffic noise was to develop an ambient noise model for the study area previous to the development of the new interstate. In order to do this, the SPreAD-GIS toolbox was used. Option 1 under the toolbox is “Create Ambient Sound Condition Dataset.” When this tool was selected, a number of

inputs were necessary for developing the dataset. The frequency of the sound to be modeled was needed to be input. For this model, 800 Hz is used, as a mean value.

In addition, the tool asked for a landcover data set. The NLCD landcover data for Guilford County clipped to the study area was used. An additional field, titled “SPREADTYPE” was added to the data containing the seven categories that are being used by the tool. These categories correspond to the NLCD categories as follow: NLCD category 31 was assigned the “SPREADTYPE” field as “BAR” for barren land. Categories 42 and 43 were assigned “CON” for Coniferous forest. Categories 71, 81, 82 and 95 were assigned “HEB” herbaceous or grassland. Categories 41 and 90 were assigned “HWD” for hardwood or deciduous forest. Category 52 was assigned “SHB” for shrubland. Categories 21, 22, 23 and 24 were assigned “URB” for urban or developed land. Finally, category 11 was assigned “WAT” for water.

The tool also asked for various ambient sound levels based on the different types of environments which were set up previously. Each of the seven categories listed above had a baseline value. For this model the values used were 20 dBA for BAR; 29 dBA for CON. 23 dBA for HEB; 23 dBA for HWD; 25 dBA for SHB; 35 dBA for URB; and 20 dBA for WAT. These values were used based on the suggestion of the developers of the SPreAD-GIS software.

The resulting map shows a baseline starting value for decibels in the study region previous to any road environment (figure 3.1). The yellow indicates where noise levels are the greatest because of already present urban activity, such as business and traffic.

## Ambient Noise Baseline

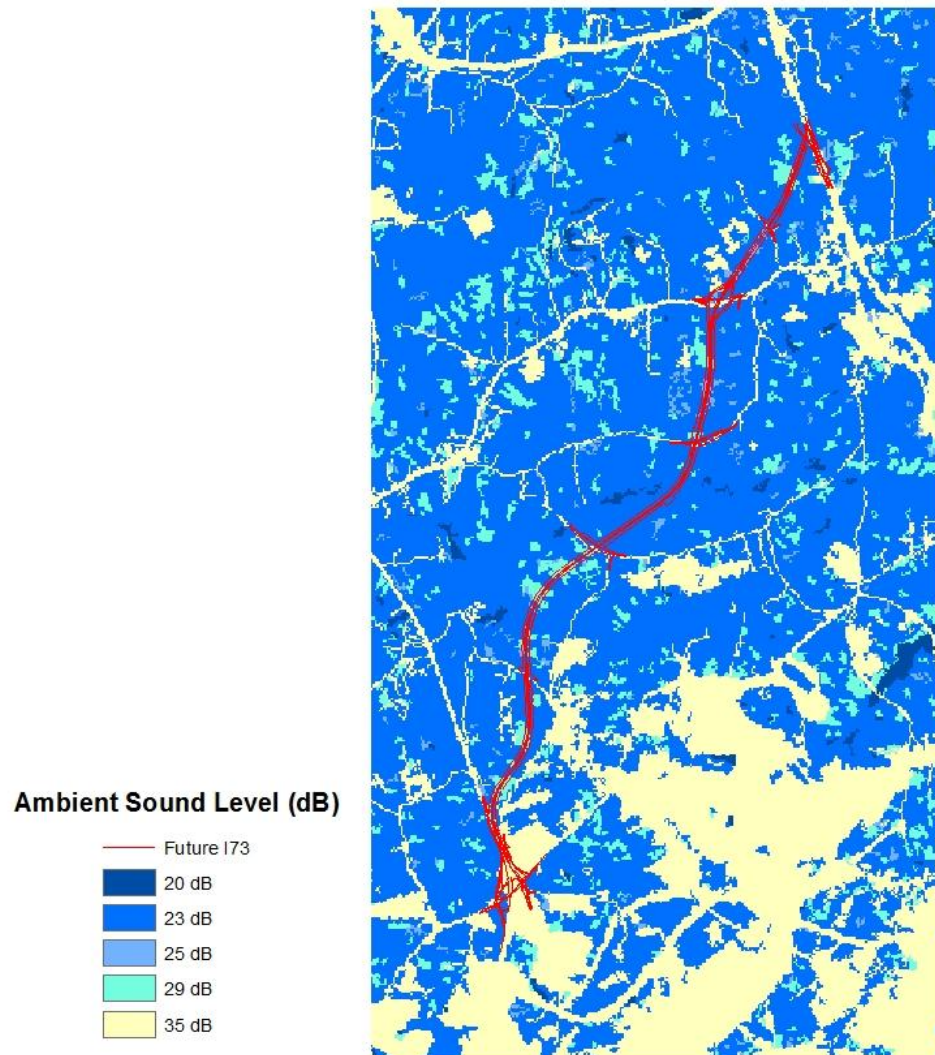


Figure 3.1. Ambient Noise Level – Future Interstate 73



The darker blue indicates areas in which sound levels are minimal, due to heavy ground cover, which will block some of the already present noise. The red line indicates the future interstate 73 route through the study area.

#### *Developing a Baseline Traffic Volume for Future Interstate 73*

One of the major factors that impact the propagation of sound is distance from the source of the sound. The source of the sound in this study is the anticipated volume of traffic along a highway that will be constructed in the near future. Therefore it is necessary to try to predict the environment of the traffic volume of this highway as it will be in the future. The factors which will influence the outcome of the model will be number of vehicles per hour as well as percentage of heavy vehicles each hour.

In order to predict the number of vehicles per hour, an examination of highway traffic volume of similar highways was performed. Interstate 73 will, of course, be an interstate, so local interstates in Guilford County were used as surrogates. Interstates 40 and 85 each carry between 90,000 and 120,000 vehicles per month through the Greensboro area. It is not expected that Interstate 73 in northwest Guilford County will carry nearly this much traffic for a number of reasons. First of all, both Interstate 40 and Interstate 85 connect large population centers within the state of North Carolina, such as Raleigh/Durham, Charlotte, Greensboro and Winston-Salem. Interstate 73 will effectively connect Greensboro to Martinsburg, VA and Roanoke, VA, two much smaller population centers. Therefore, while carrying Interstate traffic, the total amount of traffic should be significantly less.

Second, Interstates 40 and 85 connect many significant population centers nationally, such as Atlanta, Washington DC, Nashville and Memphis. Interstate 73 is routed to eventually connect to Columbus, OH, but that section has no planned date to be completed. Currently, the planned route for Interstate 73 is from Myrtle Beach, SC to Roanoke, VA, with Greensboro being the most significant population center along the planned route. Because of this, it is expected that traffic flow along this interstate will be significantly less than what is measured on Interstates 40 and 85.

Two alternate routes examined in an attempt to predict the traffic volume of the future Interstate 73 are US Highway 52 from Winston-Salem to Mount Airy, NC and US Highway 29 from Greensboro to Dansville, VA. Both these highways are proposed to become Interstate highways in the future: Highway 52 will become Interstate 74 as soon as upgrades can be made to the design of the roadway so it will conform to interstate highway standards; Highway 29 is proposed to become Interstate 785 sometime after the Greensboro Urban Loop is completed. The routes of these two roads connect a large urban center (Greensboro/Winston-Salem) with a much smaller urban area, which mimics what Interstate 73 will eventually do. In addition both of these highways are 4 lane divided highways with most or all sections access fully controlled.

The portion of Highway 29 which will help to predict the volume of the new Interstate 73 section will be in north east Guilford County from Cone Blvd. to the county line. In this section the 2009 traffic volumes range between 22,000 and 47,000 vehicles per month. These numbers had been very consistent since 2003, so it is expected that these would be accurate for the present. For Highway 52, the section that will be

examined will be north Forsyth County. In this section, the 2009 traffic volumes range from 36,000 to 54,000 vehicles per month. These data are also fairly consistent since 2003.

In proposing a traffic volume number for the purpose of this model, the estimated value should be a higher estimate, but not unreasonably high. There is good reason to believe that this section of road will have significant traffic volumes. First of all, Interstate 73 will connect people living north of Greensboro to the Piedmont-Triad International Airport. Neither Highway 29 nor 52 connect to a full service, passenger airport. Second, Interstate 73 will provide a direct route to Roanoke, VA and to Interstate 81 which travels to central Pennsylvania and New York. Highway 29 does not connect to a major Interstate until it connects with Interstate 64 in northern Virginia. Highway 52 connects to Interstate 77 via a 16 mile section of Interstate 74 near the North Carolina/Virginia border, but the next significant city that Interstate 77 connects to is Charleston, WV.

In examining these factors, it does not seem unreasonable to use 50,000 vehicles per month as a baseline traffic volume to predict traffic noise along the Interstate 73 corridor in Guilford County. It is possible that the traffic volume for this section of road could be significantly more or less. Until the road is built, it is impossible to make a 100% accurate prediction, but this number seems to be a fair estimate.

#### *Calculating the Source Noise Level*

The noise level for traffic volume at its source requires a number of variables in order to predict the noise level. There are a number of mathematical formulas which are

used to predict the noise of traffic at its source. Many deal with the volume created by one vehicle at a static point in time. For this model, these formulas will not suffice in predicting traffic noise along the whole Interstate 73 corridor.

Pamanikabub and Tansatcha (2009) developed a formula for an uninterrupted flow of traffic. This model, called CORTIN, uses a number of variables to predict traffic noise (Pamanikabub and Tansatcha 2009). The model that was used for this study is a simplified model based on the CORTIN model. The model predicted source traffic noise by examining a Reference Level Basic Noise Level and adding to it a Speed Correction and a Heavy Vehicle Adjustment.

Pamanikabub and Tansatcha (2009) set forth a Basic Noise Level formula:

$$L_{10} = 42.2 + 10 \log_{10} q,$$

Where  $L_{10}$  equals the hourly basic noise level in decibels (dBA) and  $q$  is the hourly number of passenger cars. This formula assumes a traffic speed of 75 km/h (approximately 47 miles/hr). The traffic volume per month was converted to vehicles per hour by dividing 50000 by 30 days (an average month) divided by 24 hours/day. The result was about 70 vehicles per hour.

Since the model was run for several different road conditions based on time of day, this number was adjusted for each model. For the normal mid-day traffic flow, 70 vehicles/hour was used. This formula resulted in a baseline decibel level of 60.65 dBA. For rush hour conditions, the model used 150 vehicles per hour, resulting in a baseline

decibel level of 63.96 dBA. For overnight conditions, the model used 30 vehicles per hour, which resulted in a baseline decibel level of 56.97.

The stretch of Interstate 73 to be built will be designed for 70 mph traffic flow. The Pamanikabub and Tansatcha (2009) model is developed for approximately 47 miles/hour, so a Speed correction formula was used to adjust for speeds. The formula includes parameters for adjusting for the amount of heavy vehicles. This formula is:

$$C = 33 \log_{10}(V + 40 + 500/V) + 10 \log_{10}(1 + 5 p/V) - 68.8,$$

where V is the mean traffic speed in km/h, and p is the percentage of heavy vehicles. For this model the mean traffic speed is set at 110 km/h which is approximately 70 mph. The percentage of heavy vehicles used is 33 for normal daytime and rush hour conditions and 50 for overnight conditions. The result is a correction factor of 7.24 for daytime and rush hour conditions and 8.59 for evening conditions. These corrections are added to the baseline decibel level to give total source decibel levels of 68.07 for normal daytime conditions, 71.20 for rush hour conditions and 65.56 for overnight conditions.

#### *Modeling Noise Propagation Based on Distance*

As a general rule, traffic noise will decrease by 3 dB every time the distance doubles. In order to predict how the traffic noise from the future Interstate 73 corridor affected households in the study area, a model giving distance needed to be developed. This study computed and used “Euclidean Distance” from a feature as the distance measurement.

The first step in determining the noise propagation based on distance was to compute the Euclidean Distance. The Interstate 73 polyline shapefile was used as the input feature for distance calculation. This produced a raster dataset where each cell centroid in the raster represents a distance from the nearest line segment along Interstate 73. A maximum buffer distance of 5280 feet was used to correspond to the study area. This was done to ensure that the output raster covers the full study area.

The next step included the computation of distances from the source of the noise. The starting value for each of the three models were calculated using the Pamanikabub and Tansatcha (2009) model, which are 71.20 for the heavy traffic model, 68.07 for the daytime traffic model and 65.56 for the overnight traffic model. The output rasters are calculated using the following formula:

$$L_p = L_w - \log (4 \pi r),$$

where  $L_p$  is the observed sound level in decibels at a point distance  $r$  in meters from the source with a source sound level of  $L_w$ . For  $L_w$ , the three starting decibel values were used. For  $r$ , the distance raster values were input. These were converted from feet to meters in order to get an accurate sound level value. The output rasters are shown in figure 3.2. The output of all three of these raster looks similar because the variable that affects the sound level is solely based on distance from the highway. Red indicates regions which are mainly located near the highway and thus are the most affected by the traffic volume. For the heavy traffic model, these areas represent decibel levels greater than 70. For the overnight model these levels are significantly less, only about 60-65

decibels. Yellow regions represent decibel levels between 40 and 60. The green regions represent decibel levels less than 40, which is only a slight increase over the ambient sound levels.

## Sound Levels Based On Distance (dBA)

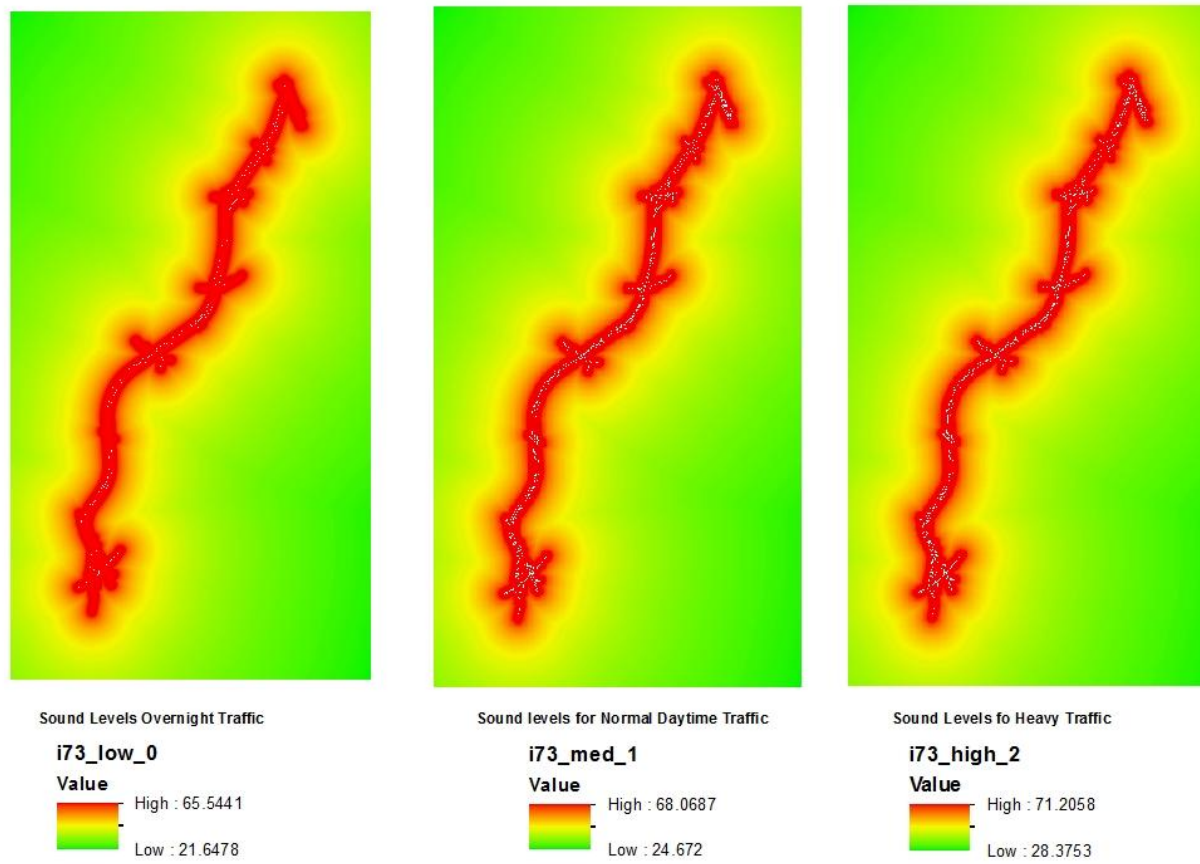


Figure 3.2. Sound Level Values Based on Distance from Source



### *Calculating the Effect of Landcover on Sound Level*

The next step in developing this model is to take into account the effect of landcover on the propagation of the highway noise from the future Interstate 73 corridor. Using the categories from the SPreAD-GIS model, a NLCD file which had been clipped to the extent of the study was reclassified to fit these categories (figure 3.3). The landcover features were reclassified into seven categories. Barren, undeveloped areas were classified into the BAR category, represented by tan on the map. The light blue regions, which represent areas of water, whether lakes, streams or rivers, were classified as WAT. Yellow regions represent herbaceous areas and were classified as HEB. This was used to categorize regions of tall grasses as well as farm fields, which would have a similar affect on sound levels. Orange represents areas categorized as shrublands or SHB. Light green represents areas of hardwood forest and were classified as HWD, while dark green represents areas of coniferous or mixed forests and were classified as CON. Finally, the dark grey represents both light and dense urban areas and were classified as URB.

These new classifications were used to determine how much of the sound from the Interstate 73 traffic is absorbed by a variety of vegetation within the study area. In order to do this these 7 classes were reclassified into a percentage loss number. According to the Reed, et. al. (2010), areas classified as hardwoods absorb the most sound energy. Therefore for this model they were given the value 10. Coniferous areas were given a value of 8 for mixed forest areas and a value of 7 for coniferous forests. A value of 6 was assigned to wet land areas with hardwood forest growth. Herbaceous,

agricultural and shrublands were assigned a value of 2. Dense urban areas were assigned a value of 1, while all other urban areas and areas of water were assigned a value of 0 (Table 3.1).

Table 3.1. Classification Values for Vegetation Types

Classification Values for Vegetation Types	
Vegetation Type (NLCD)	Classification Value
Deciduous Forest (Hardwoods)	10
Mixed Forests	8
Evergreen Forests (Coniferous)	7
Woody Wetlands	6
Grassland, Sedge, Pasture/Hay, Cultivated Crops	2
Developed High Intensity	1
Developed, Medium and Low intensity, open space, barren, open water	0

The classification values for vegetation type were plugged into a formula to determine the new sound propagation levels based on both distance and landcover. This formula is:

$$L_{lc} = L_p - (L_p * (\text{Landcover Value}/100)),$$

where  $L_{lc}$  is the new sound level generated from the Interstate 73 traffic,  $L_p$  is the sound level raster created using the distance model and the Landcover Value is the number listed above. The resulting raster outputs are shown in figure 3.4.

In comparing the results of the first calculation, without the adjustment for landcover, with this new calculation, a number of results are apparent. First, the maximum sound level which is experienced remained unchanged. This is to be expected, since at a minimal distance from the road, there should be little landcover that will affect the propagation of the traffic noise. Another observation is that with the distance only models, the noise levels experienced are symmetrical around the proposed interstate. Once the landcover data is added, regions are observed that experience less sound loss than other regions. This is particularly true around interchanges and overpasses where there is little to no landcover to absorb the sound. These places are where the existing roads are located and thus many properties, which will be affected by the highway noise, are located adjacent to these areas.

## Landcover Types

### Landcover Types

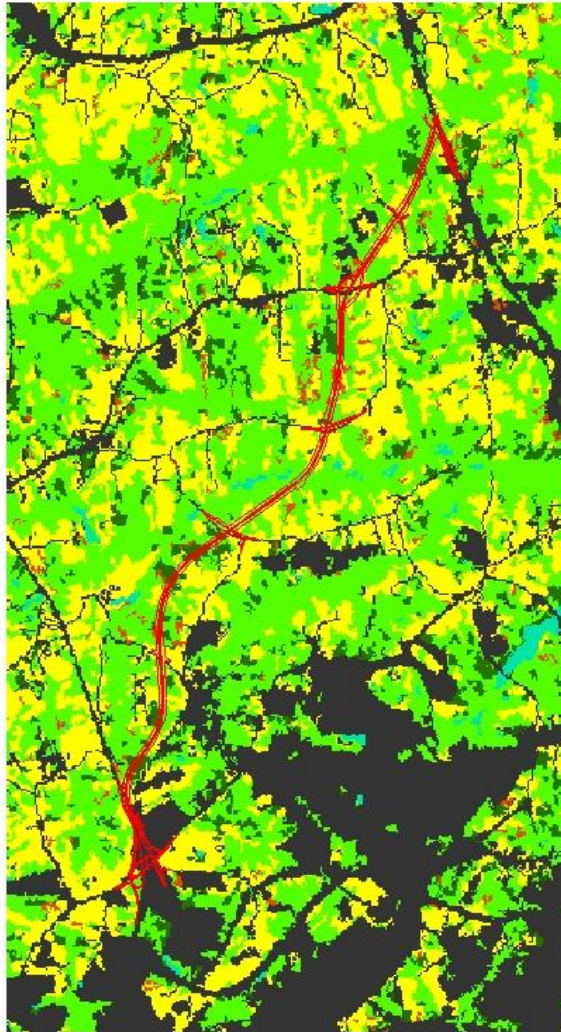


Figure 3.3. Reclassified Landcover Types

### Sound Levels Based on Distance from Source and Landcover

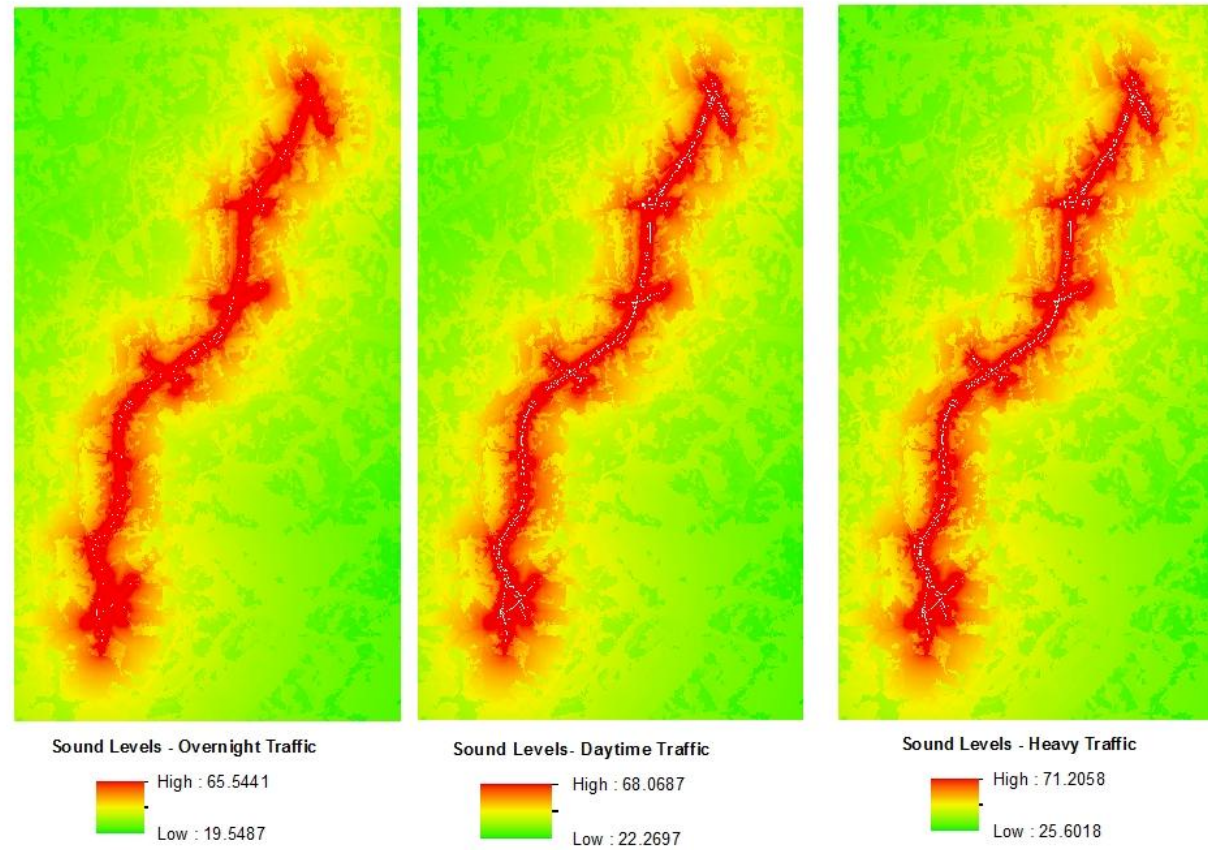


Figure 3.4. Sound Levels from Interstate 73 Based on Distance from Source and Landcover

### *Calculating the Effect of Elevation on Sound Levels*

Elevation is the last factor used to predict traffic noise levels. In many sound models used in mountainous regions, the actual elevation has an effect on how the sound is propagated. However, within this study region, the elevation range is from 571 feet to 976 feet. Because of this, the effect of elevation on the sound levels was negligible. However, sound will pool into low lying regions, so this model took into account the affect of elevation on sound levels.

In the same way that the landcover data was used to modify the sound levels based on distance from the source, the DEM modified the previously calculated sound levels. In order to do this, the DEM was reclassified to a -10 to 10 scale, with the lowest elevation having a 10 value and the highest elevation having a -10 value (Reed, et. al. 2010). These values were used as percentage gain or percentage loss based on whether or not the location had a high elevation, which would tend to reduce the amount of sound carried from the Interstate, or a low elevation, which would tend to pool the sound. Looking at a flow map, the observer can easily identify low lying areas that would more readily capture the sound between areas of higher elevation (figure 3.5).

The reclassified DEM was used to predict how the sound moves over higher elevations and through lower elevations. Using the sound level rasters developed in section 3.4 and the initial sound level rasters based solely on distance from the source, the new sound level was calculated using the percentage gained and lost using the following formula:

$$L_{\text{Final}} = L_{\text{lc}} + (L_{\text{p}} * (\text{Elevation Value} / 100)),$$

where  $L_{\text{Final}}$  is the models final output sound level in decibels,  $L_{\text{lc}}$  is the sound level raster after adjusting for landcover,  $L_p$  is the sound level raster based solely on distance and Elevation Value is the adjusted elevation raster with values from -10 to 10. Again, this model was run for overnight traffic, normal daytime traffic and heavy traffic levels. Results are shown in figure 3.6.

Some interesting patterns develop by comparing the final results shown in these maps to the results shown considering only distance from the sound source and the results shown considering both distance and landcover. First, the maximum sound levels experienced from the results of this model are very similar to the results of the other two calculations. This is because the major factor in determining sound levels from traffic volume is distance. Sound levels nearest to the proposed interstate should not be greatly affected by either landcover or elevation and this model correctly predicts that they are not. Second, the pattern of the noise levels is even less symmetrical than what is seen from running the model only considering distance and landcover. This shows that the valleys and hills should have some effect on the amount of noise experienced in any given location.



## Flow Direction Map of the Interstate 73 Study Area

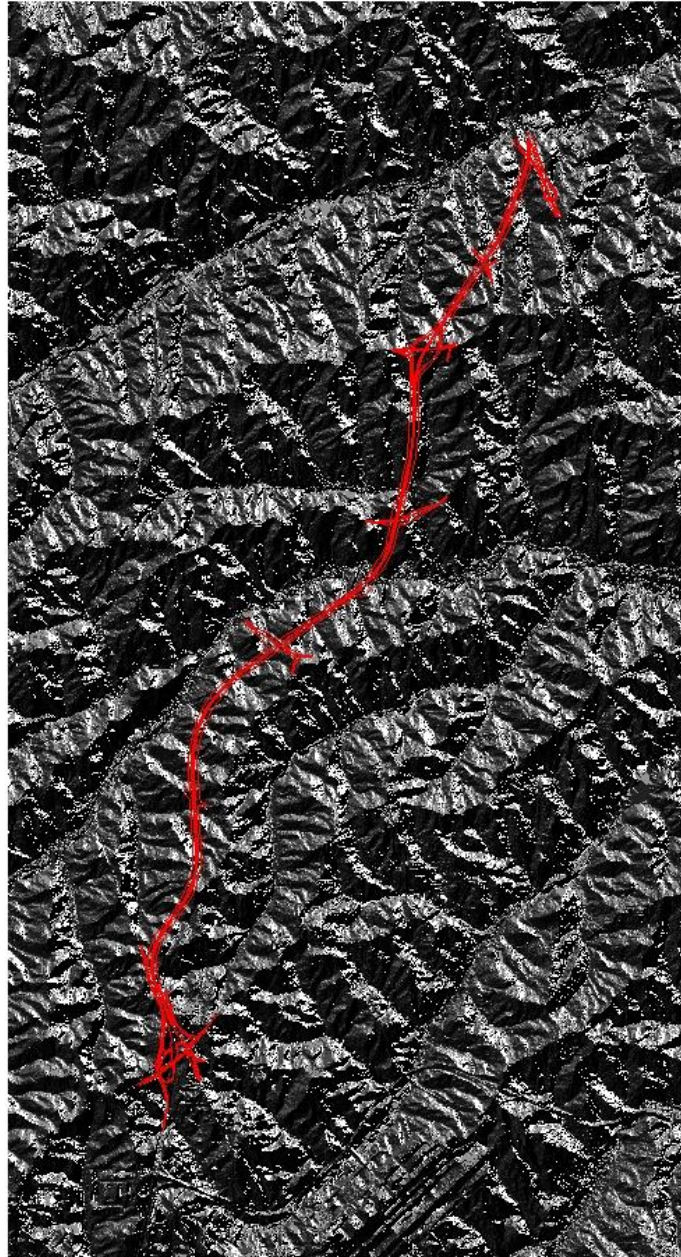


Figure 3.5. Flow Direction Map – Interstate 73 Study Area



## Sound Levels - Future Interstate 73 Corridor

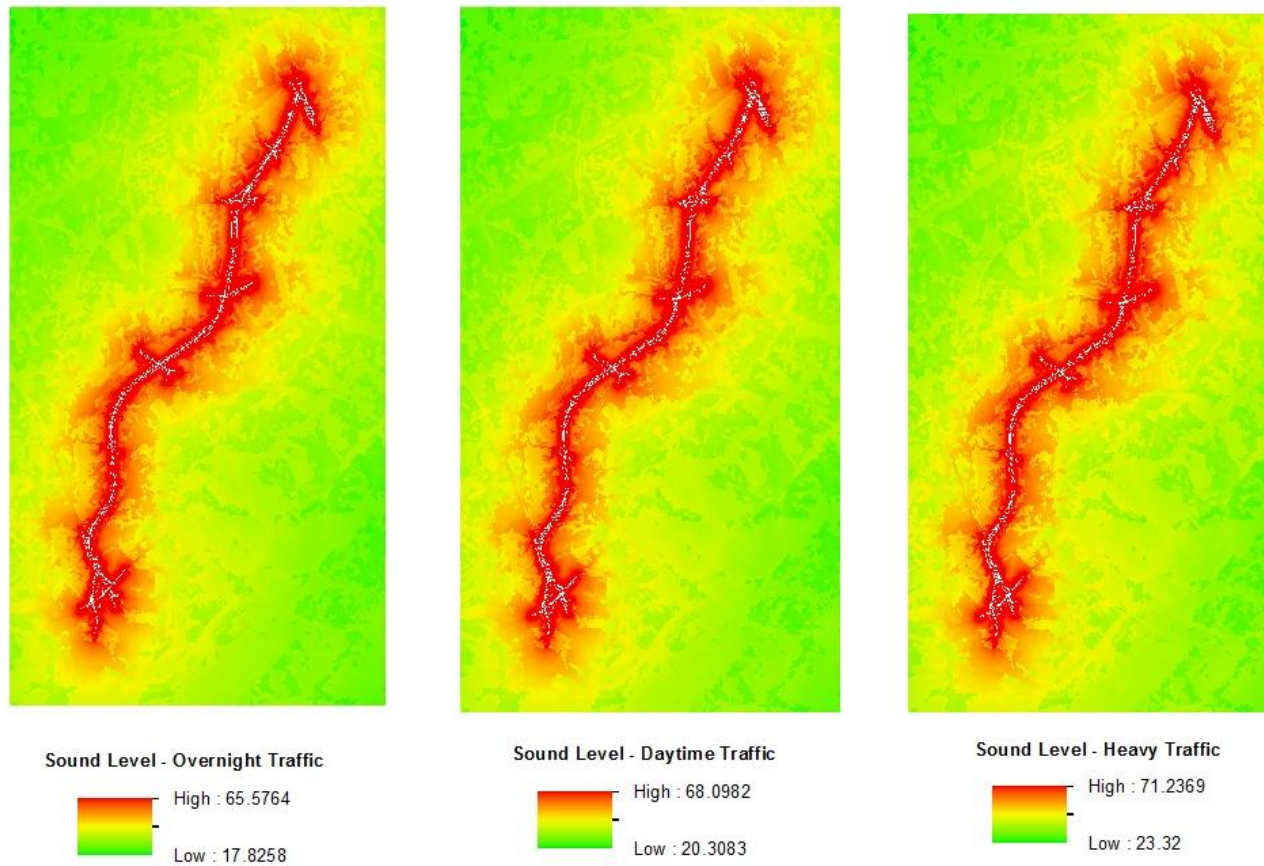


Figure 3.6. Final Sound Level Rasters for the Future I73 Corridor.

## **CHAPTER IV**

### **MODEL RESULTS**

As expected, higher traffic noise levels resulted nearest to the proposed Interstate highway route, because noise levels attenuate exponentially over distance. Most of the homes which are affected the most by the potential highway noise are located less than a mile from the proposed Interstate.

There are a number of ways to evaluate the results of these models. Three of these methods were used for each of the traffic models developed. The first was to look at the overall noise decibel level for the proposed Interstate as a whole. This was done by creating an isoline map showing the different sound levels that result from the predicted highway noise. By looking at these data, a pattern for where the greatest sound level increases was revealed.

The second method was to look at the decibel level change between the predicted highway noise levels and the ambient sound layer before the highway development. This was done by taking the final sound level raster for each of the three conditions and subtracting out the ambient sound level raster created using SpreAD- GIS. In order to remove any negative differences, since traffic noise will never make sound levels decrease, all 0 and negative values were set to a null value.

Finally, several critical noise areas were dealt with on a larger scale. These were evaluated by both the final sound level raster as well as the sound level change raster for areas of high increase in sound level and areas of dense concentration of houses and other buildings. Most of these clusters are close to the highway and it was expected that sound levels would increase in these areas.

#### *Results of the Overnight Traffic Model*

The first method to analyze the data was to look at the overall sound levels which are generated by the proposed highway traffic. For the overnight model, the base estimated vehicle levels were 30 vehicles per hour with 50 percent heavy vehicles. This was facilitated by creating a contour map showing the sound levels from highway traffic (figure 4.1)

Looking at the contour map of the expected sound level, some interesting patterns emerge. First of all, there appears to be a relatively uniform pattern to the contour lines as the distance from the sound source increases. This pattern seems to indicate that the primary factor in determining sound level is distance from the source, and that elevation and landcover play a secondary role in the model.

However, the displayed pattern is not perfectly uniform. In fact there are regions in which the sound decreases less dramatically than others. One conclusion that can be made is that the effects of elevation and landcover, while not the primary factor in sound propagation, have a definite effect on the noise level experienced at any given location.

## Overnight Traffic Sound Level Contour Map

### Sound Level

- Proposed I 73
- Contours
- 35 dBA Contour

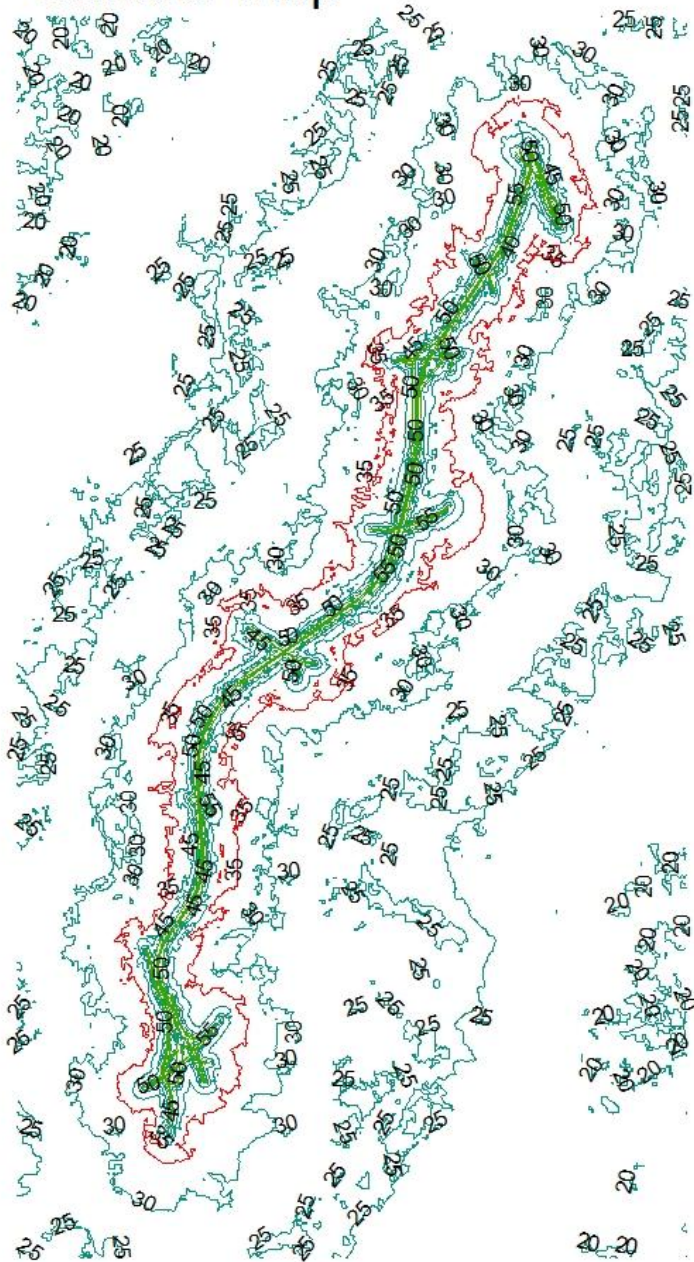


Figure 4.1. Sound Level Contour Map, Overnight Traffic

For landcover, the regions of lesser sound decrease are regions in which the landscape is open, such as barren or urban landcover, or regions in which landcover is not sufficient to block out a majority of the sound, such as grasslands, shrublands and agricultural lands. Conversely, dense wooded areas have a greater impact in reducing the sound levels experienced. This shows that the model developed follows what would be expected logically.

Similar results are shown concerning the effect of elevation on sound levels. In lower lying elevations, especially those that are in a bowl or valley type area, the expected result would be to see sound levels decrease very little due to the terrain capturing the sound. Likewise, those areas of higher elevation would experience less effect from the traffic noise and thus the sound levels would show a greater decrease over these areas. Again the model seems to perform well in capturing the effects of the terrain on noise levels.

One last pattern that is seen from the contour map is the locations of significant decibel increase. Since the highest ambient starting sound level is 35 dBA, identifying areas in which the experienced sound level is 35 dBA or greater will show where traffic noise will have a significant effect on the experienced noise levels. This is shown in figure 4.1 by the red contour line, which represents the 35 dBA noise level threshold. The region of the study area which is between this contour and the proposed Interstate 73 route is the area which is affected by significant traffic noise. When measuring the distance of the 35 dBA contour from the proposed route, the result shows that this area is between  $\frac{1}{4}$  and  $\frac{1}{3}$  mile.

The second method to evaluate the effect of traffic on sound levels is to look at the decibel level change between the predicted highway noise level and the ambient sound levels before highway construction. For the overnight traffic model, the results are shown in figure 4.2. From the straight sound level increase map, the higher areas of increased sound level, shown by the yellows, oranges and reds, are located mostly within a half mile from the proposed Interstate route. These areas represent values of approximately 8 dBA increase or greater. Since every 3 dBA increase doubles the sound volume, these are areas of significant increase.

When overlaying the study area polygon, the result is that there are a few areas of significant sound level increases outside of the one mile buffer. However, most of the area outside of the study area is not showing large increases in sound level; some areas are only showing increases of 0 – 1 decibel.

The third method of analyzing the results is to look at specific areas of significant increase along with areas of comparatively dense build up. There are three areas in which these two factors seem to be maximized (Figure 4.3). Study area one is located near the southern end of the proposed Interstate route and includes a large cluster of homes which would be affected by the highway noise.

## Sound Level Increase - Overnight Traffic

with Study Area Overlay

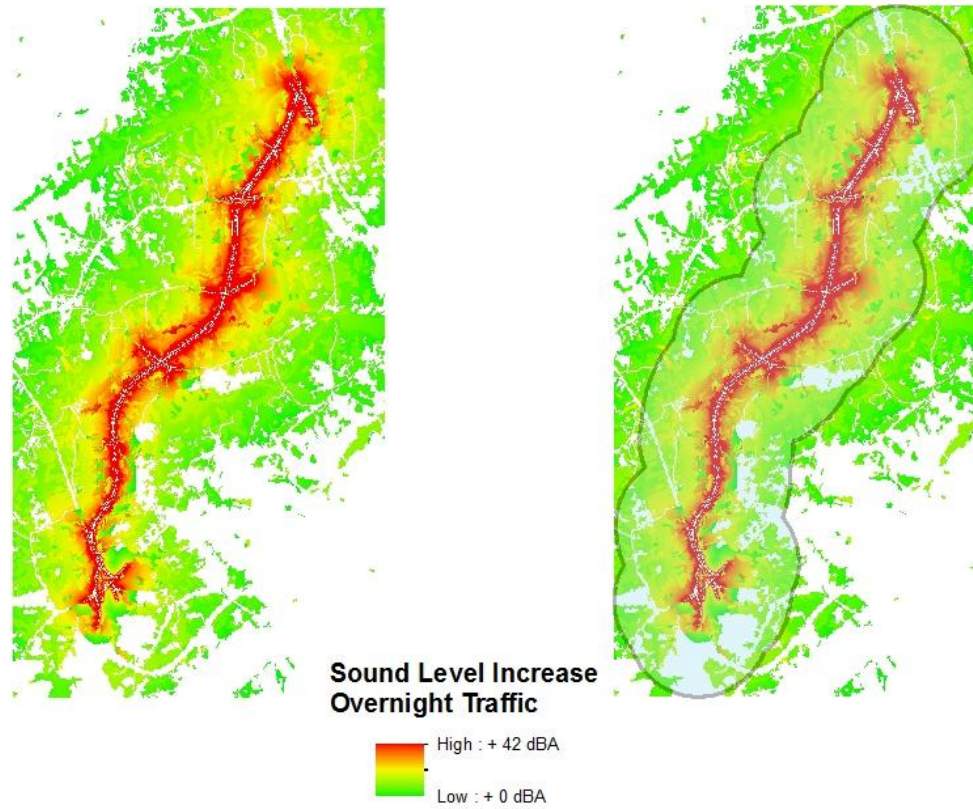


Figure 4.2. Increase in Sound Levels, Overnight Traffic, Interstate 73



One result from study area one is that the range of decibel increase for the buildings in this area is 0 to 22.5 dBA. Some of the areas which had no increase were areas in which the ambient decibel level was already defined at 35 dBA because of the classification of this area as urban. Due to the effect of sound level loss over distance, by time the traffic noise reaches these buildings, it has been reduced to 35 decibels. These results are not out of line. However, setting the urban ambient decibel level at 35 dBA assumes consistent urban traffic and noise. Although these areas are classified as urban, because they are so far from an urban center, it is quite possible that these areas do not have sustained noise levels of 35 dBA, and thus the effect of traffic noise would not be so much of an increase in maximum noise levels, but a more sustained or consistent noise level.

What is of greater significance is the areas that experience a 22 dBA increase in noise. The general rule is that the actual noise doubles or is twice as loud for every 3 dBA increase. Therefore, there are a number of buildings which will experience a sevenfold increase in noise. This is a significant and noticeable increase.

Study area two is located midway along the Interstate route. This area has a significantly less concentration of houses than study areas one or three. What makes this area significant is that the smaller cluster of residences is located within an extremely high area of sound increase.



## Selected Study Areas

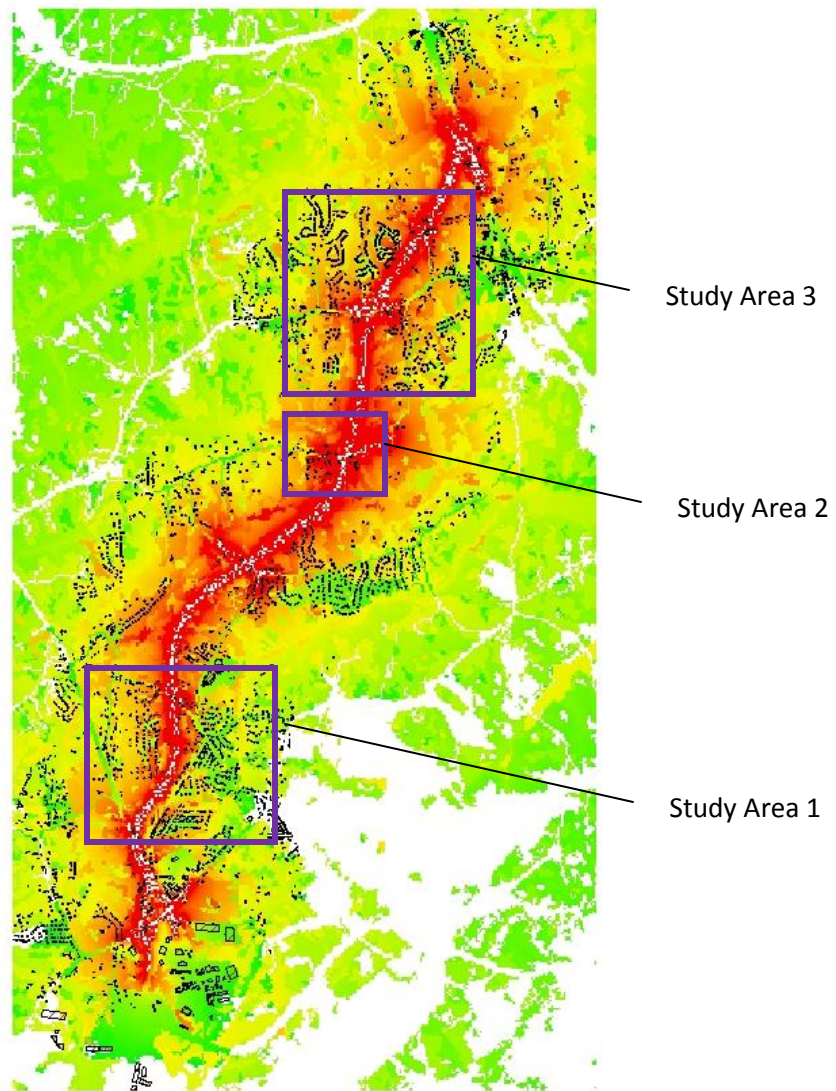
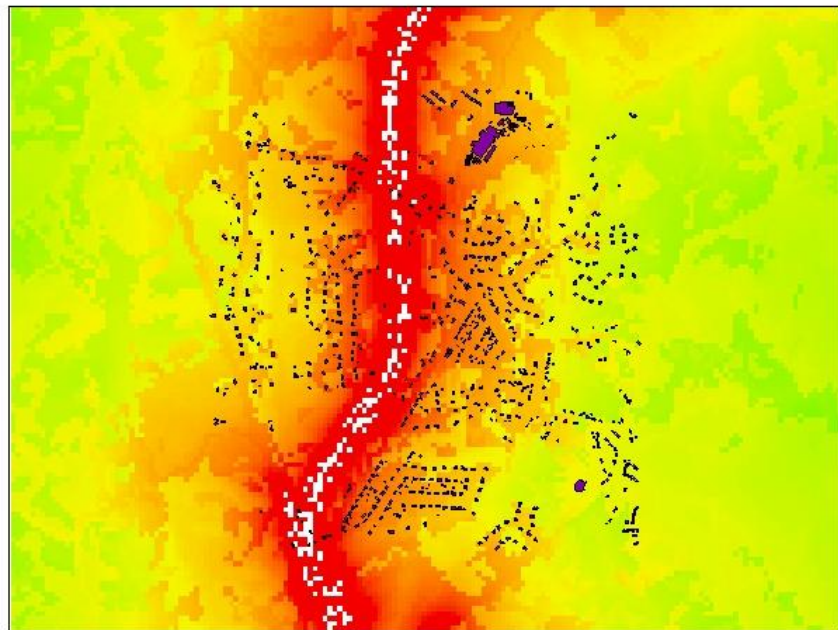


Figure 4.3. Selected Study Areas, Overnight Traffic

## Study Area 1 Results, Overnight Traffic

Total Sound Levels, dBA

**Sound Level**



Change in Sound Levels, dBA

**Sound Level Change**

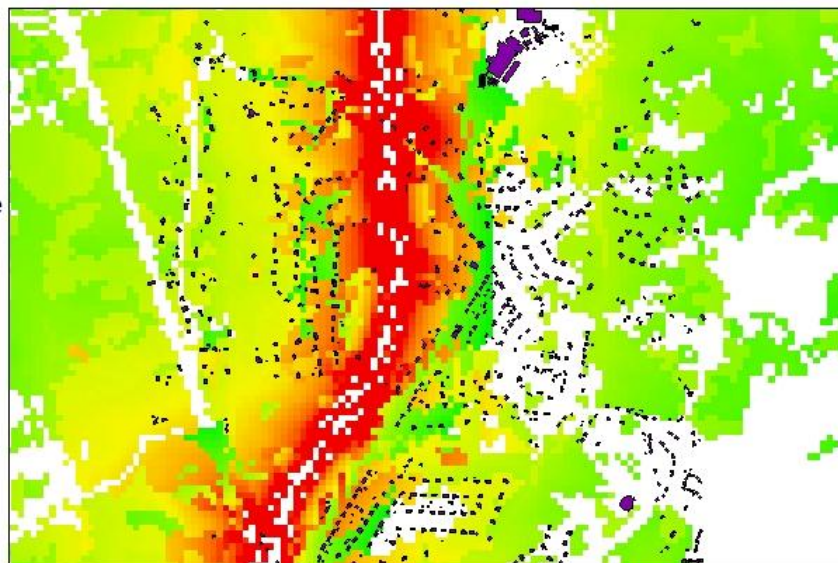


Figure 4.4. Study Area 1, Overnight Traffic

Study area number two shows similar results (figure 4.5). The buildings affected by the traffic show and increase decibel level of 7 to 32 dBA. The 32 dBA increase constitutes the difference between someone whispering in a quiet library from 6 feet away to someone talking at normal conversation levels at a distance of 3 feet. The building with the highest predicted overall decibel level has a value of 59 decibels. This is about the level of normal conversation at 3 feet.

Study area three, which is the largest study area with the most buildings shows a wide range of results (figure 4.6). The third study area is located in the northernmost section of the proposed Interstate route. This study area contains one of the more dense areas of development and encompasses an area of newer development. The ranges of sound level increase are from 0 to 31 dBA. The highest level observed for a building which is not in the right-of-way of the future project is about 61 dBA, which is consistent with the other two study areas. This model predicts that noise levels are consistent throughout all three study areas, and that due to the small difference in elevation and consistent landcover over the entire study region, the noise levels due to highway traffic are going to be similar throughout the proposed interstate route.

Since these results describe the overnight model, it could be argued that these results still would not constitute a consistent noise level, but that they only describe peak noise levels generated as there is traffic on the Interstate. However, two factors should be considered when determining the significance of these results.

## Study Area 2 Results, Overnight Traffic

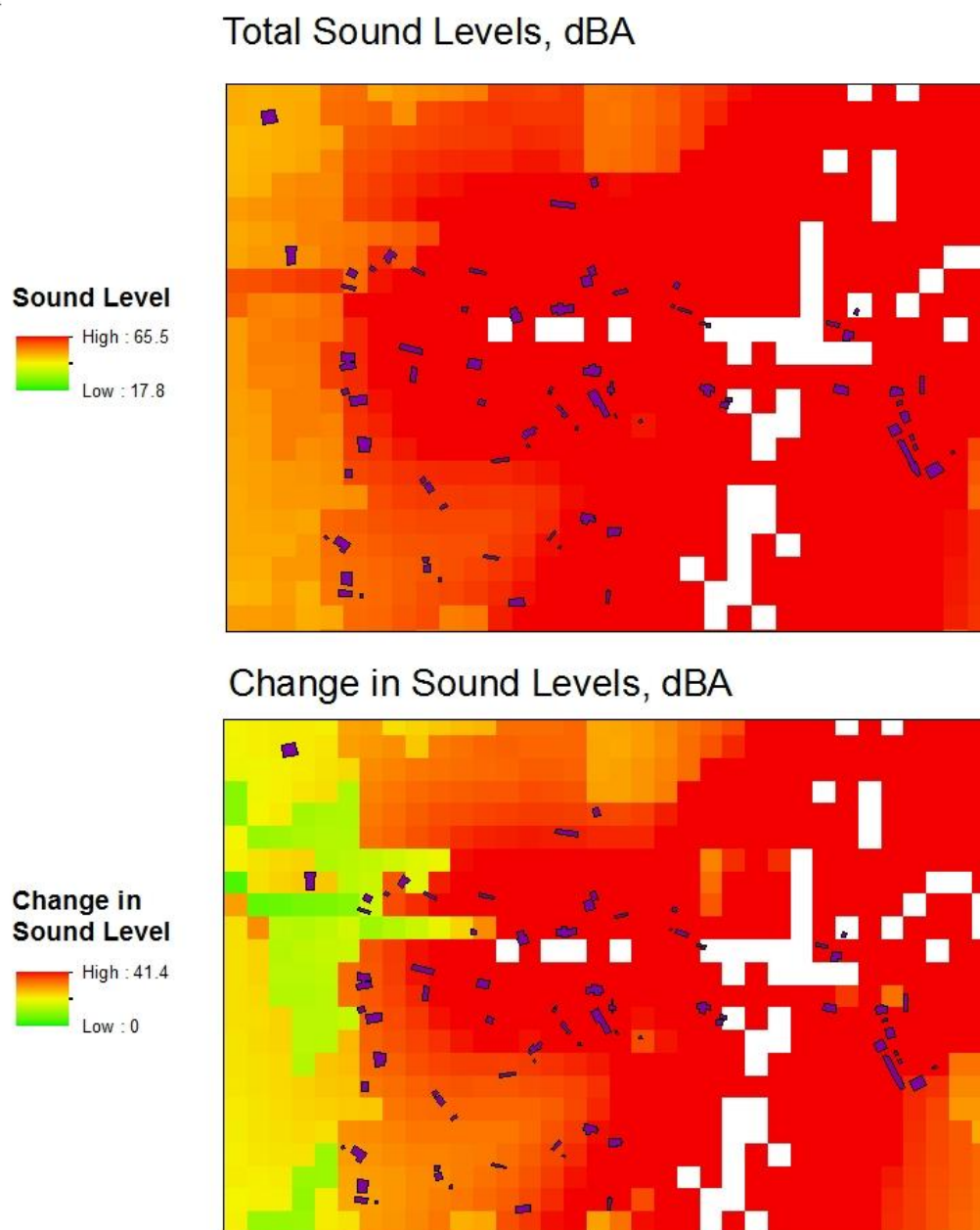


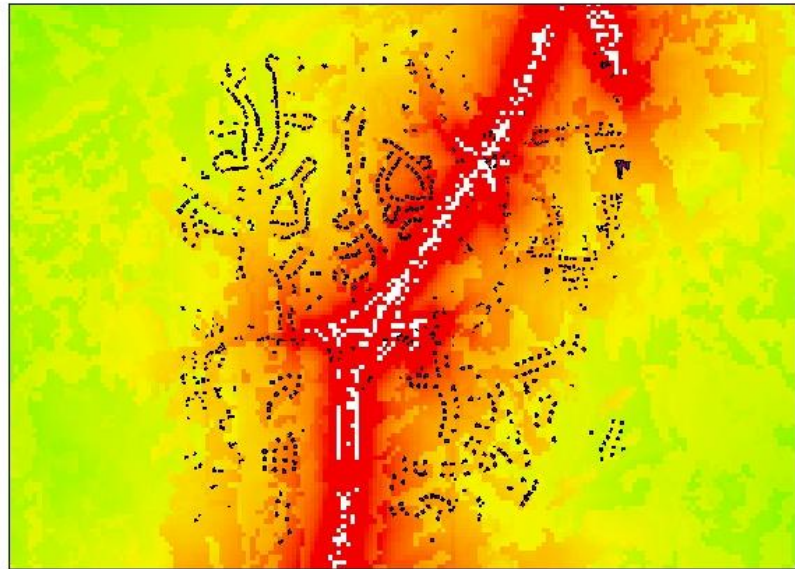
Figure 4.5. Study Area 2, Overnight Traffic



## Study Area 3 Results, Overnight Traffic

Total Sound Levels, dBA

Sound Level



Change in Sound Levels, dBA

Change in  
Sound Level

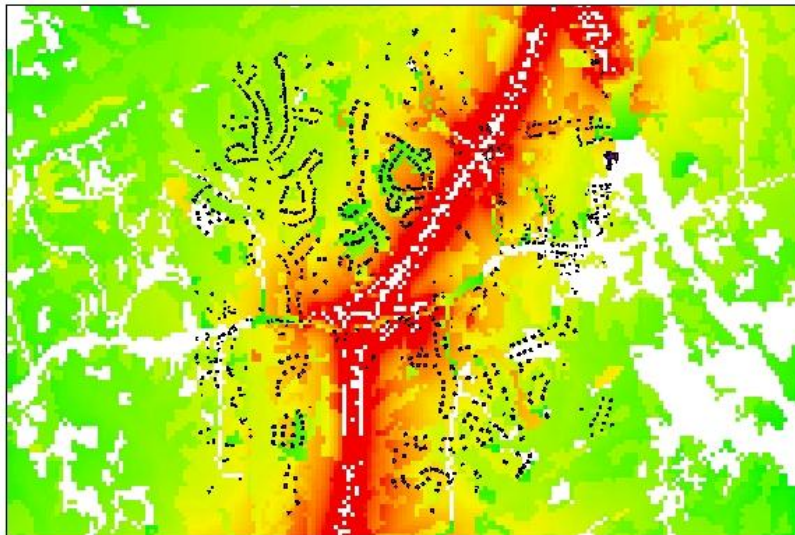
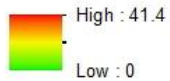


Figure 4.6. Study Area 3, Overnight Traffic

First, since these results assume an overnight traffic flow, much ambient noise, especially in developed areas will be decreased, resulting in a lower baseline noise level. This would mean that any increase in noise levels would be perceived as more significant.

A second factor to consider is that a majority of people who would be affected by the traffic noise are much less active in the overnight hours than they would be during normal daytime hours. This causes greater sensitivity to the highway noise, especially if the homes in which those affected by the traffic noise are dwelling are insufficient in their noise insulation.

#### *Results of the Daytime Traffic Model*

Due to the fact that the main difference between each of these models is the starting decibel level from the traffic noise source, many of the patterns and conclusions that are drawn from both the daytime traffic model and the heavy traffic model are going to be similar. The main difference that the model demonstrated is in the experienced decibel level and then in the amount of change in decibel levels from the ambient levels. These differences will be discussed briefly in this section.

The first result of the model examined below is the significant sound level area resulting from traffic noise. This was done using the contour map of the sound levels with the 35 dBA contour selected as the threshold of significant sound increase (figure 4.7). A significant increase in the maximum extent of the 35dBA contour from the proposed interstate occurs with the daytime traffic. This extent increases to a maximum of about 0.6 miles from the new interstate. The difference in the source sound levels between the overnight traffic model and the daytime traffic model is about 3 dBA.

However this 3 decibel increase results in a significant difference in the amount of area affected by traffic noise. For a visual comparison between the extent of the significant traffic noise predicted by the overnight model and the daytime model, see figure 4.14. The second factor that was examined is the difference between the predicted sound level and the ambient sound level. In the daytime model the highest predicted value of highway sound level is 3 dBA greater than the overnight model. This results in an increase of sound levels in more areas as compared to the overnight traffic. The differences are between 0 and 3.4 dBA increased sound levels in the daytime model. Figure 4.9 shows the differences in the sound level increases between the two models. An interesting result that is seen from a comparison of these two models is that the area of greater sound level increase between the daytime traffic model and the overnight traffic model is in areas further away from the proposed interstate. Conversely, areas near to the interstate have a less significant increase in sound level between the two models. While most of the concern for highway noise is for those who are in closer proximity to the highway, it is significant to note that those who are 0.5 to 1 mile away may be affected significantly as well.

## Daytime Traffic Sound Level Contour Map

**Sound Level**

- Proposed I 73
- Contours
- 35 dBA Contour

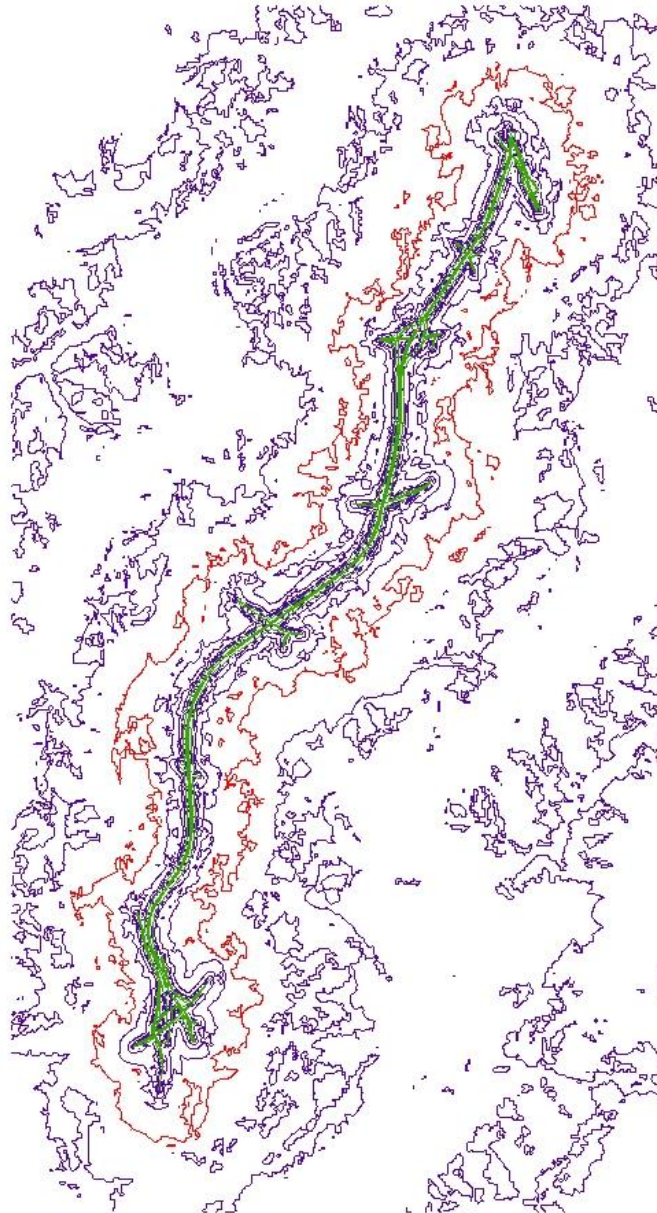


Figure 4.7. Sound Level Contour Map, Daytime Traffic



## Sound Level Increase - Daytime Traffic

with Study Area Overlay

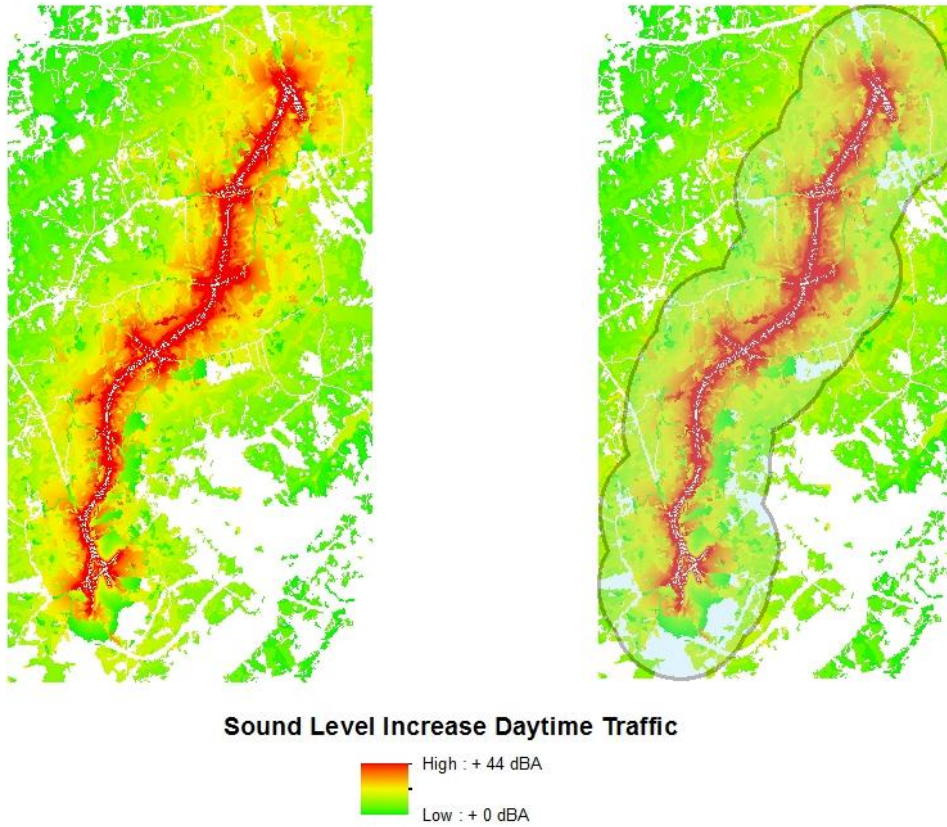


Figure 4.8. Increase in Sound Level, Daytime Traffic, Interstate 73

There is little to no difference in the areas of urban landcover. One reason might be because the urban areas started at a significantly higher ambient sound level.

Therefore, since the difference was calculated by subtracting the ambient sound level from the predicted sound level and that any negative values are set to zero, the difference reaches the zero value over a much quicker distance in regions which are categorized as urban.

Ignoring these results, the areas which show the greatest difference in sound levels between the two models are areas categorized as water and herbaceous. These areas diminish the sound levels the least and thus, create a greater difference between the two models. The areas with the least difference are the areas categorized as hardwood. These areas diminish the sound levels the most and so a greater difference in source sound levels has a less significant difference in these areas.

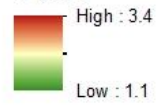
The third result of the model which will be examined is the sound level increase predicted in particular study areas. For consistency, the same three areas as in the overnight model will be examined. In study area 1 (figure 4.10), those buildings which are within several hundred feet of the interstate are seeing traffic noise levels between 49 and 63 dBA. This is a slight increase from the maximum decibel level of 59 which was seen in the overnight model. In comparison, the amount of increase in decibel levels increases to a maximum of 28 decibels for buildings near to the proposed interstate route.

## Difference in Sound Level – Overnight to Daytime Traffic

Difference in Increased Sound Levels (dBA)

Comp\_ML

Value



Proposed I 73

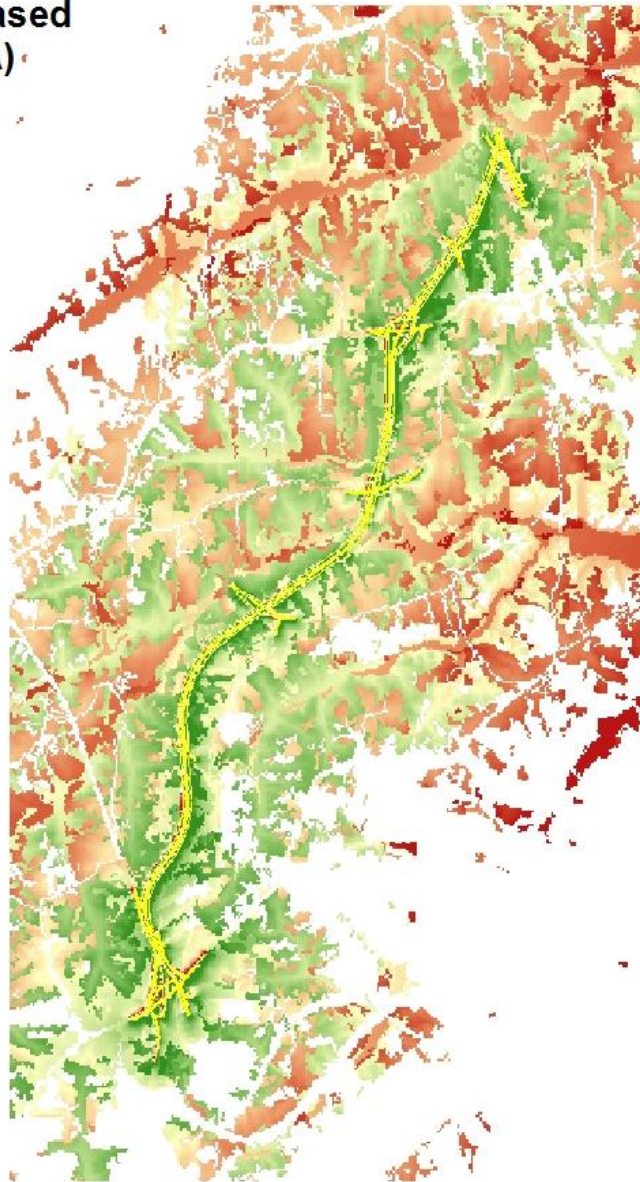


Figure 4.9. Difference in Predicted Sound Levels, Overnight and Daytime Traffic

## Study Area 1 Results, Daytime Traffic

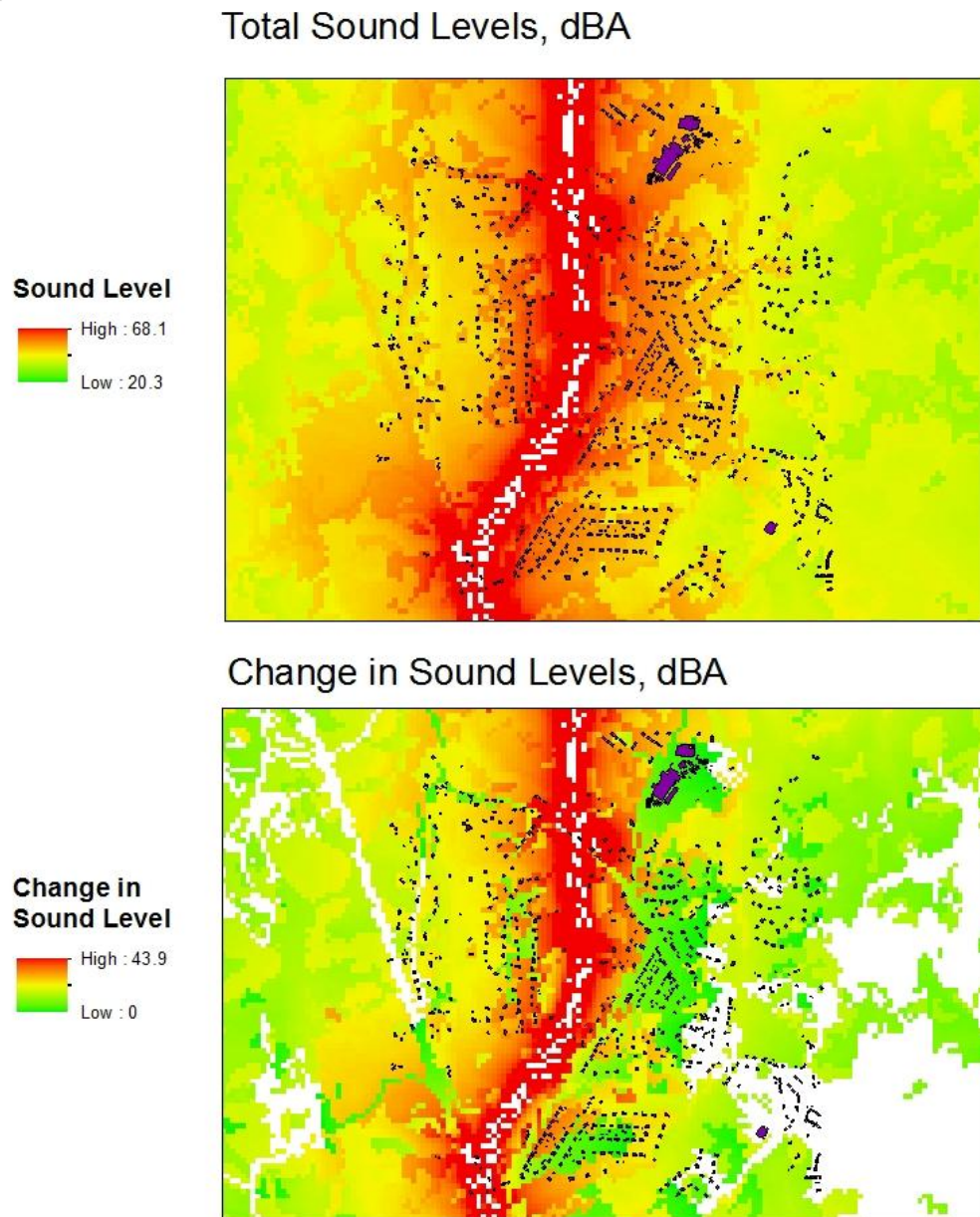


Figure 4.10. Study Area 1, Daytime Traffic

Considering an increase of three to a decibel level doubles the noise level perceived, this shows that buildings within 50-100 feet could experience noise from traffic that seems 100-400% louder than what it was before the interstate would be built.

Looking at study area 2, similar results are found (figure 4.11). Again, the building with the highest decibel level from the predicted sound level model was about 4 dBA greater than what was predicted in the overnight model. This level increased from 59 dBA to about 63 dBA. Likewise, the change in sound level from the ambient level to the daytime traffic model had a maximum value for the buildings in the study area of about 35.5 dBA. This again is expected, since the only variable between the two models is the initial starting source sound level.

In examining study area 3 (figure 4.12), the expected result would be to see decibel levels increase 3.5 to 4 dBA, based on the results seen in study areas 1 and 2. The results show that the maximum sound level experienced by a building in the study area is a little over 63 dBA, only about a 2.5 dBA increase in sound level compared to the overnight model. This is close to the 3.5-4 dBA increase, but not the same. One explanation for this result could be within the elevation or landcover models that would allow for the sound levels to depreciate quicker within this region.

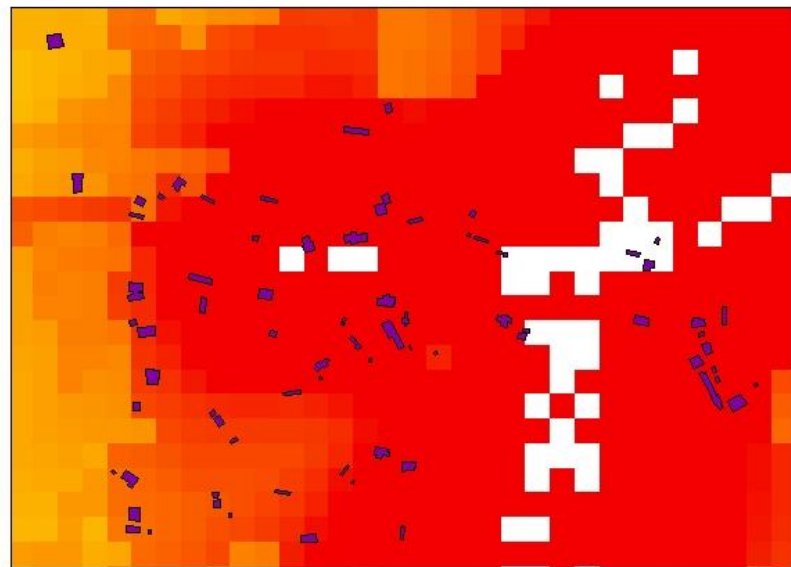
As the results are examined within these three regions for the daytime traffic model, a consistent pattern appears compared to the overnight model. Based on how this noise prediction model is built, the results are expected. As the source noise level increases, so should the noise levels of all areas within the study area.



## Study Area 2 Results, Daytime Traffic

Total Sound Levels, dBA

**Sound Level**



Change in Sound Levels, dBA

**Change in  
Sound Level**

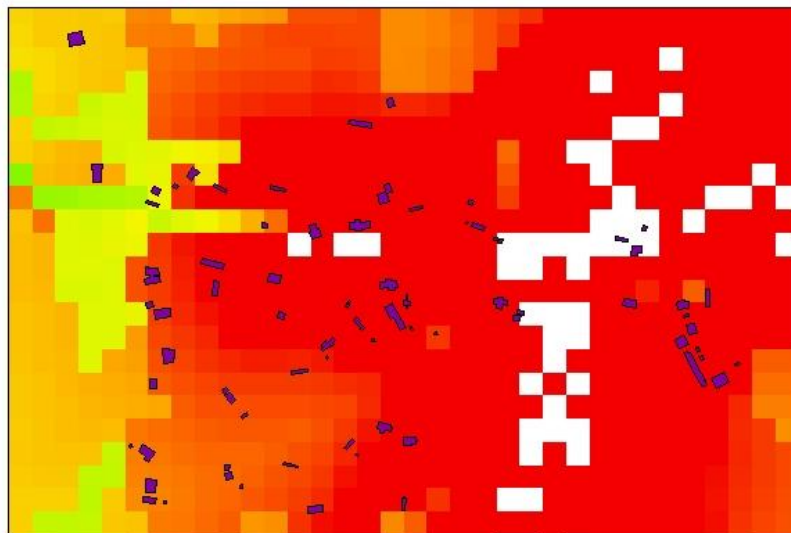
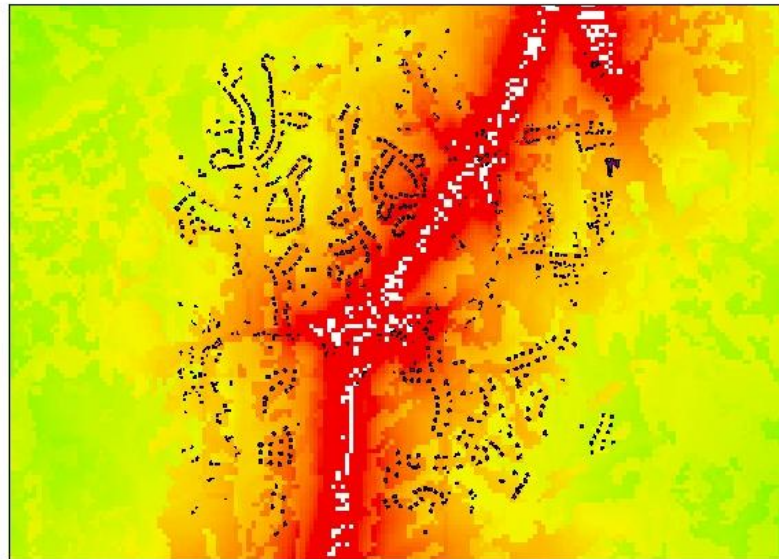


Figure 4.11. Study Area 2, Daytime Traffic

## Study Area 3 Results, Daytime Traffic

Total Sound Levels, dBA

**Sound Level**



Change in Sound Levels, dBA

**Change in  
Sound Level**

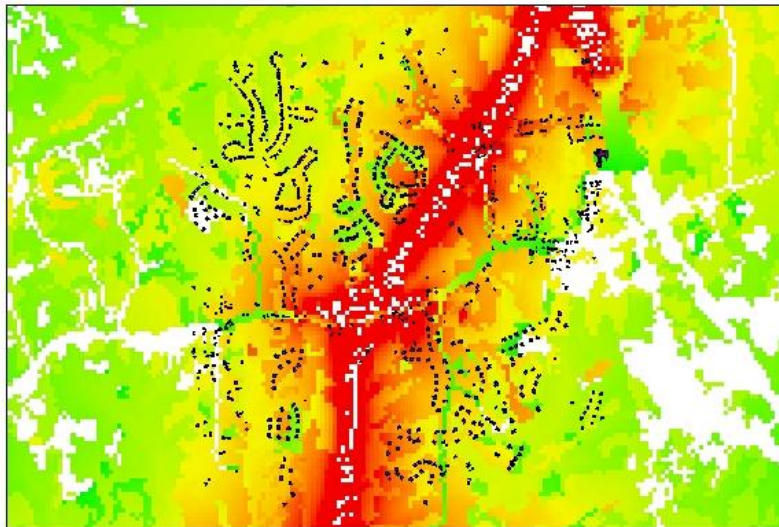
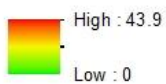


Figure 4.12. Study Area 3, Daytime Traffic

In examining the heavy traffic model, the results should be similar, because as the source noise levels increase, the expected results for the study area should be to see an increase in observed sound levels at any given point in comparison to the overnight and daytime traffic model.

#### *Results of the Heavy Traffic Model*

The first result which was examined in this model was to analyze the pattern of the contour map for the heavy traffic model (figure 4.13). The threshold for significant sound level increase which was set is at 35 dBA. In examining the distance from the source of the sound, the maximum measured distance of significant sound level increases ranges from 1 to 1.25 miles. This is about two times as far as in the daytime model and 3 to 4 times as far as in the overnight model. It should be noted that the increase in decibel level at the source of the sound from the daytime model to the heavy traffic model is only about 3 dBA.

An interesting map which shows the affects of the increase in sound levels is figure 4.14, which compares the 35 dBA contours for the overnight, the daytime and the heavy traffic models. Two significant patterns can be seen from this map. First of all, as the source sound levels increase, there is more variation in the observed sound level as distance increases from the source. This is due in part to the landcover having a greater effect on depreciating the sound levels.



## Heavy Traffic Sound Level Contour Map

### Sound Level

- Proposed I 73
- Contour
- 35 dBA Contour

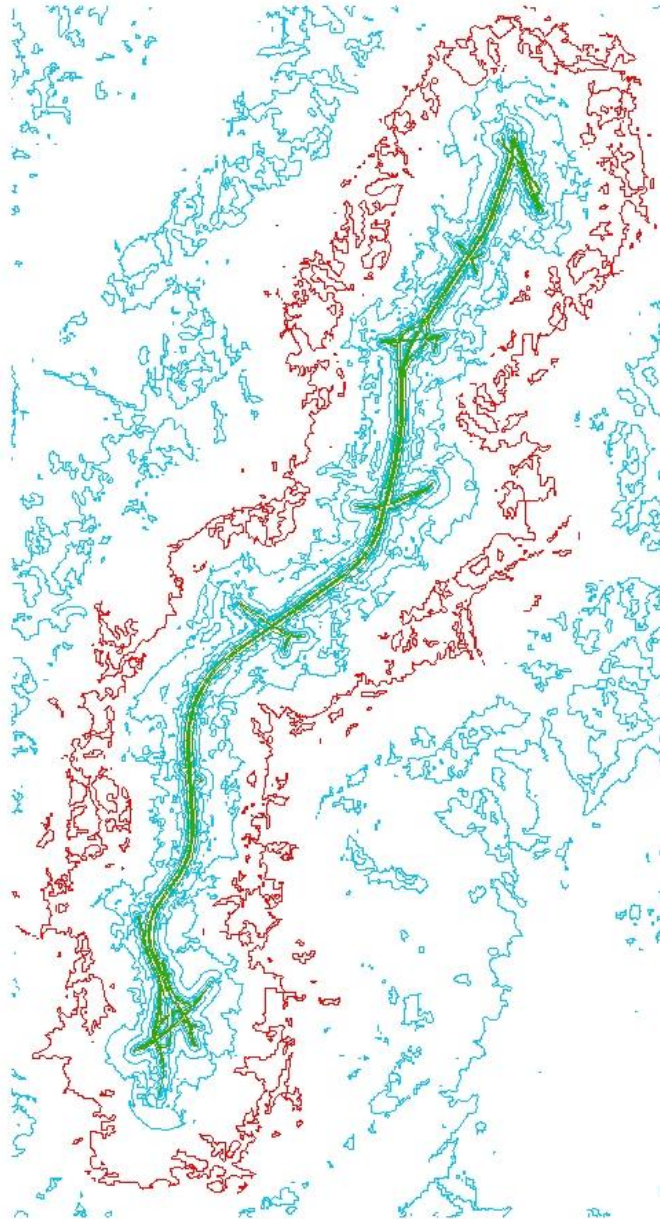


Figure 4.13. Sound Level Contour Map, Heavy Traffic

## 35 dBA Comparative Contour Map

### 35 dBA Contours

- Heavy Traffic
- Daytime Traffic
- Overnight Traffic
- Proposed I 73

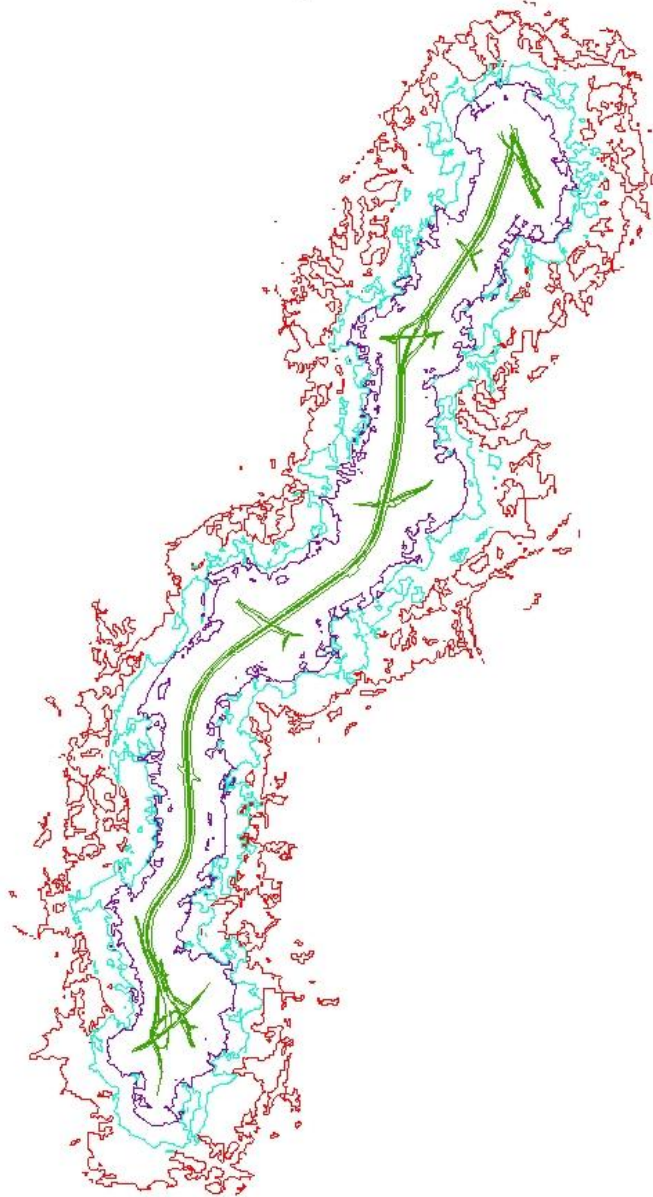


Figure 4.14. Comparative Map of 35 dBA Contours for All Three Models.

In some parts of the study area, sound levels between the three models are very similar, as shown by the close proximity of the 35 dBA contour lines of the three models to each other. In other areas, the distance between these contour lines is much greater.

A second pattern is that with the overnight model the 35 dBA contour ranges less in its distance from the sound source than for the heavy traffic model. Remember, the difference in source sound level is only about 6 dBA between the overnight and heavy traffic models. Yet, this small difference results in a great variation as to how the sound is affected by the landcover and by elevation as shown by the differing patterns of the contour lines. In the discussion section, this result will be analyzed in greater detail.

The second result that will be examined is the increase in sound levels for the heavy traffic model as compared to the ambient sound levels. This is shown in figure 4.15. The maximum sound level difference between this model and the ambient sound model is about 46.9 dBA, nearest to the sound source. This again is consistent with what is expected from the other two models. The difference between the source sound levels between the daytime and heavy traffic models is about 3 dBA and the difference between the maximum sound level differences from the ambient sound level is about 3.1 dBA.

Looking at a comparison between the sound level increase from the heavy traffic model and the overnight traffic model shows some interesting results. The results of this comparison are shown in figure 4.16. First, the difference between these two sound levels ranges from 0 to about 6.7 dBA. This is consistent with the differences in source sound levels between the two models.

## Sound Level Increase - Heavy Traffic

with Study Area Overlay

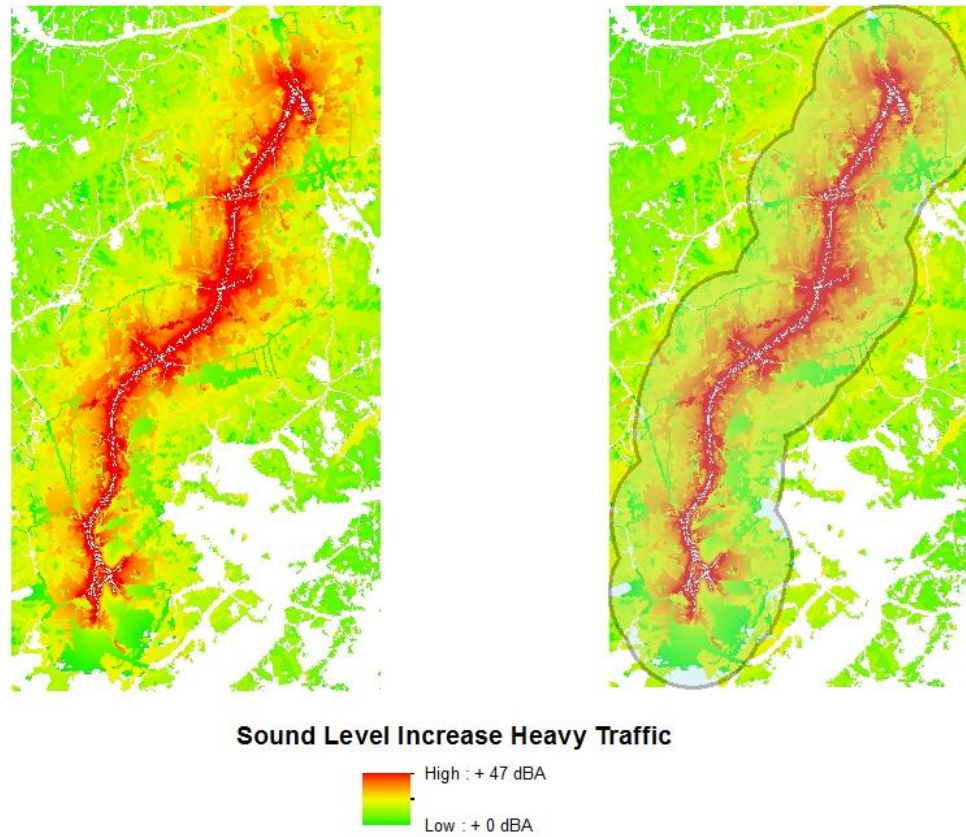


Figure 4.15. Increase in Sound Level, Heavy Traffic, Interstate 73



## Difference in Sound Level Increase, Heavy to Overnight Traffic

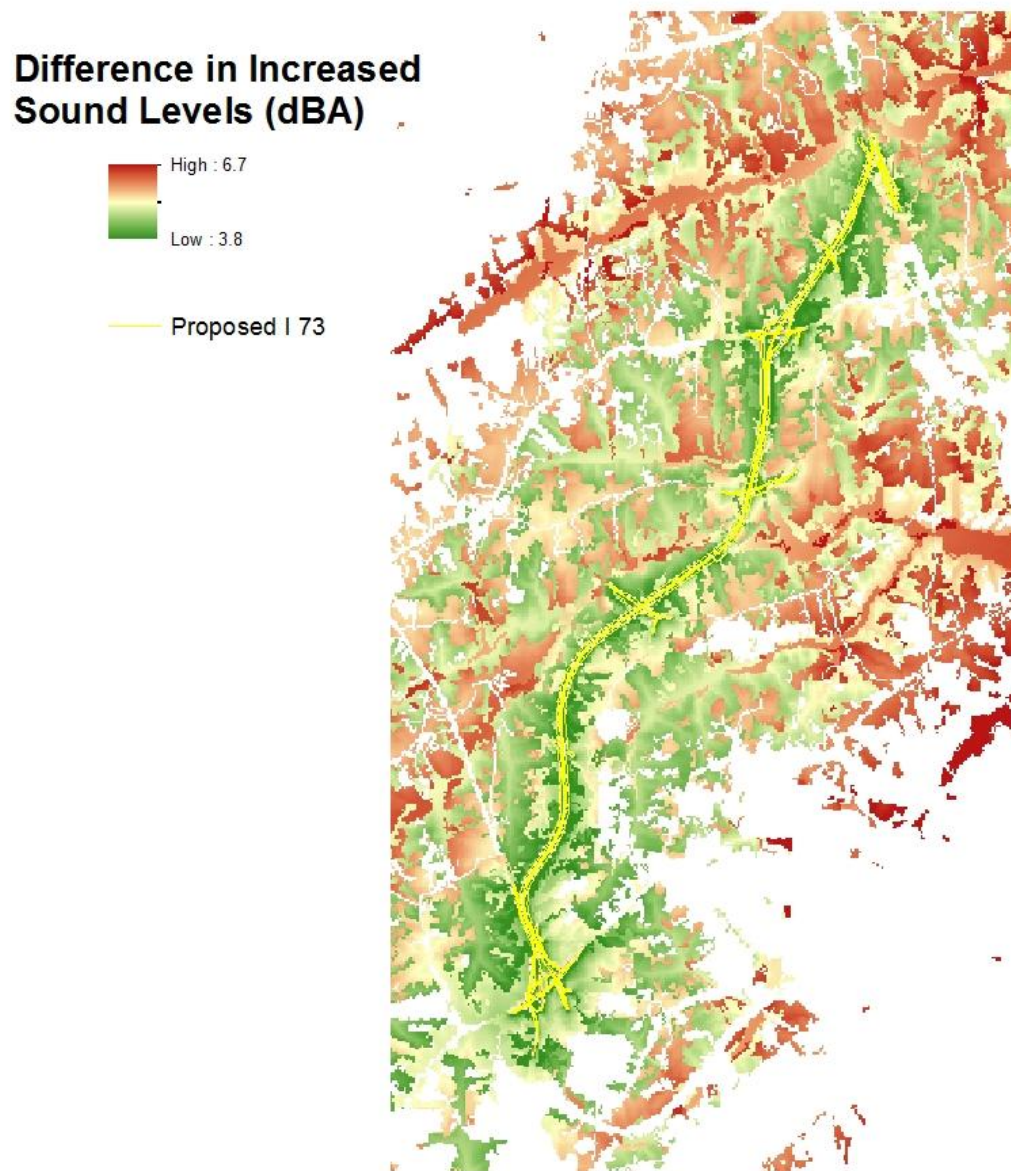


Figure 4.16. Difference in Predicted Sound Levels, Overnight and Heavy Traffic

One reason for the range of differences between these two models is that the impact of landcover and elevation has a significant effect on the propagation of the sound levels throughout the study area.

Second, as with the comparison between the daytime and overnight models, the pattern of these results is significant. The areas which show up with a result of 0 are the areas in which the ambient sound level is greatest, mainly the areas classified as urban. Those areas with lower differences between the two models are areas classified as hardwood. Hardwood areas would have a greater effect at diminishing the perceived sound levels and thus would help to equalize the sound levels between the two models. As with the daytime traffic model, the areas which show the greatest difference in sound levels between these two models are the areas classified as water and herbaceous. In other words, the more open the areas, the less diminishing of sound levels and thus the greater the sound level at the source of the sound, the more of an effect on the perceived sound levels at any given point.

The third result that is examined is to consider the effect of the traffic noise on the three defined study areas. The expected result should be similar to what we have seen for the overnight and the daytime models. The differences between the daytime traffic model and the heavy traffic model that should be expected are about 2.5 to 3 decibel increases for both the overall sound level as well as for the difference between the ambient sound level and the expected sound level due to heavy traffic.

In study area 1 (figure 4.17), we see consistent results with what is expected. The maximum value that is observed for a building in this area is 66 dBA, which is about 3

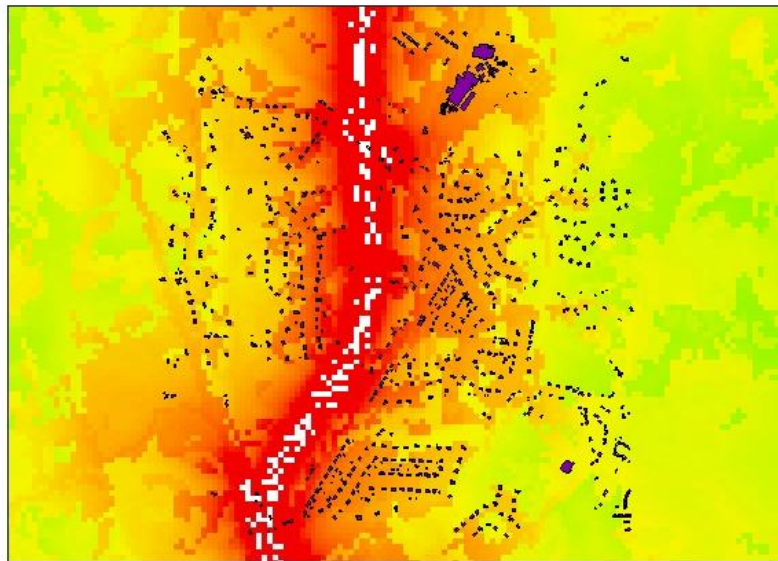
dBa greater than what was observed using the daytime model. In addition, the greatest increase from the ambient sound level is 31 dBA, which is also about a 3dBA increase from the daytime model.

Study area 2 shown similar results (figure 4.18). The building with the greatest perceived sound level has a value of 65 dBA, which is about 3 dBA greater than what is predicted by the daytime traffic model. Likewise, the sound level change from the ambient sound level is 30 dBA at its maximum, also 3 dBA greater than what is predicted by the daytime model. These results are consistent throughout study area 2.

## Study Area 1 Results, Heavy Traffic

Total Sound Levels, dBA

**Sound Level**



Change in Sound Levels, dBA

**Change in  
Sound Level**

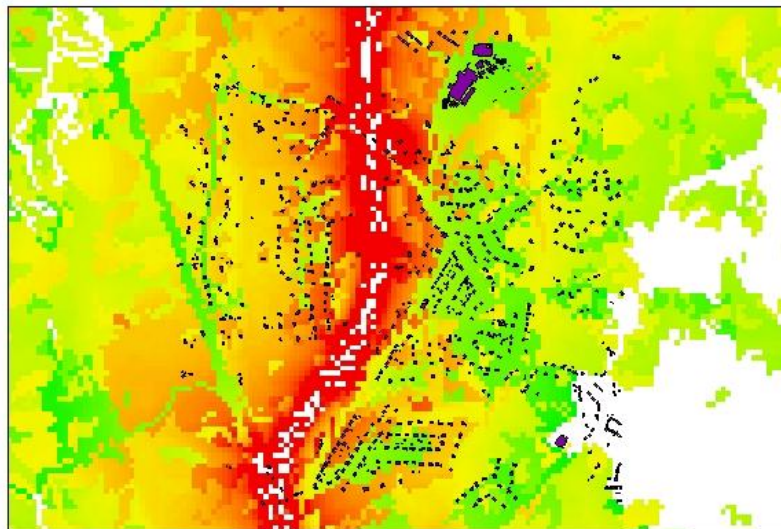
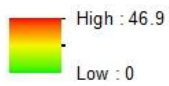


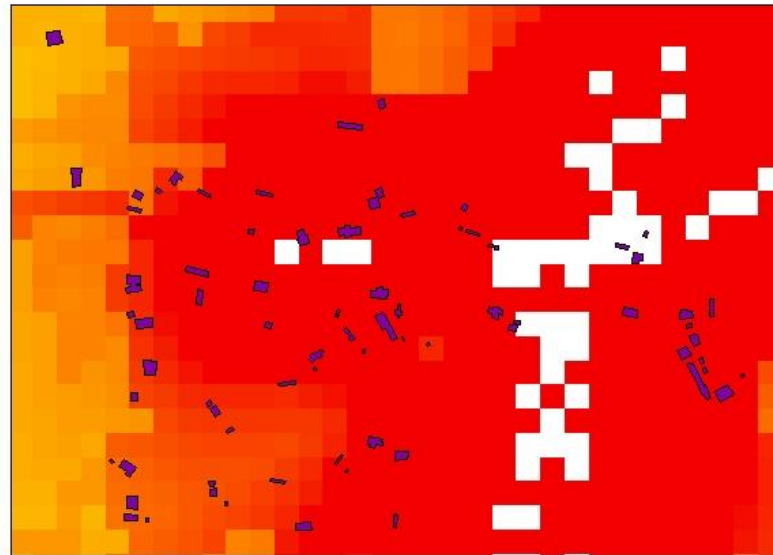
Figure 4.17. Study Area 1, Heavy Traffic



## Study Area 2 Results, Heavy Traffic

Total Sound Levels, dBA

**Sound Level**



Change in Sound Levels, dBA

**Change in Sound Level**

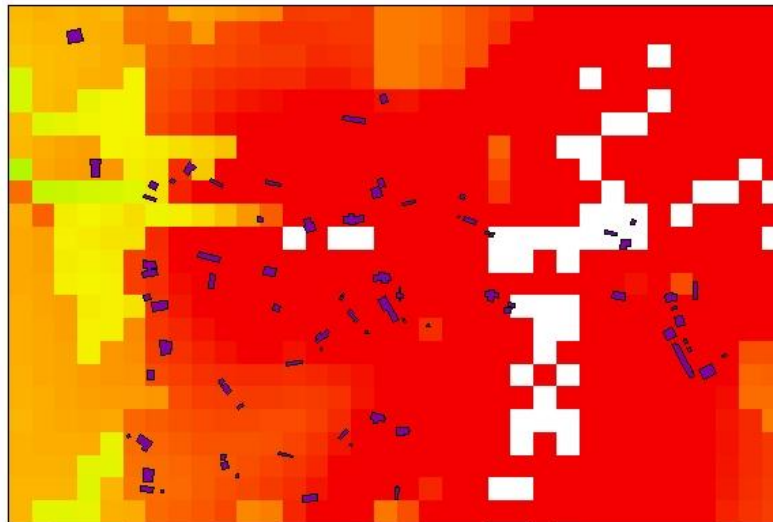


Figure 4.18. Study Area 2, Heavy Traffic

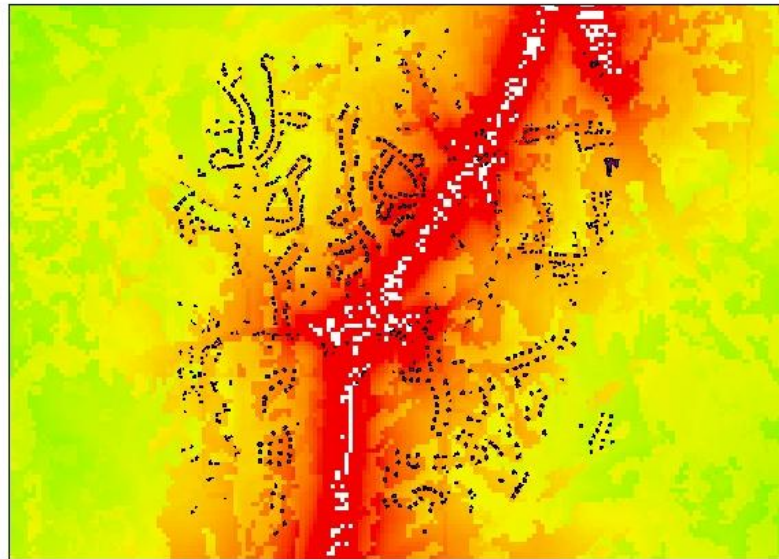
For study area 3, similar results are also observed (figure 4.19). The maximum sound level for the heavy traffic model observed by any building in the study area is 66 dBA, about an increase in 3 dBA from what is observed by the daytime traffic model. The greatest change in decibel levels between the heavy model and the ambient sound level model is about 43 dBA, which also is about a 3 dBA difference.

In looking at these results, it is important to note that a 3 dBA increase in sound levels between overnight and daytime traffic and between daytime and heavy traffic levels may not seem like very much. However, because the decibel scale is a logarithmic scale, what a 3 dBA increase in sound level amounts to is a perceived doubling in sound level to the human ear. Therefore one of the conclusions that can be drawn from the noise prediction models is that as traffic increases at various times of the day, it has a significant effect on the sound levels of places within a mile from the source of the sound.

## Study Area 3 Results, Heavy Traffic

Total Sound Levels, dBA

**Sound Level**  
High : 71.2  
Low : 23.3



Change in Sound Levels, dBA

**Change in Sound Level**  
High : 46.9  
Low : 0

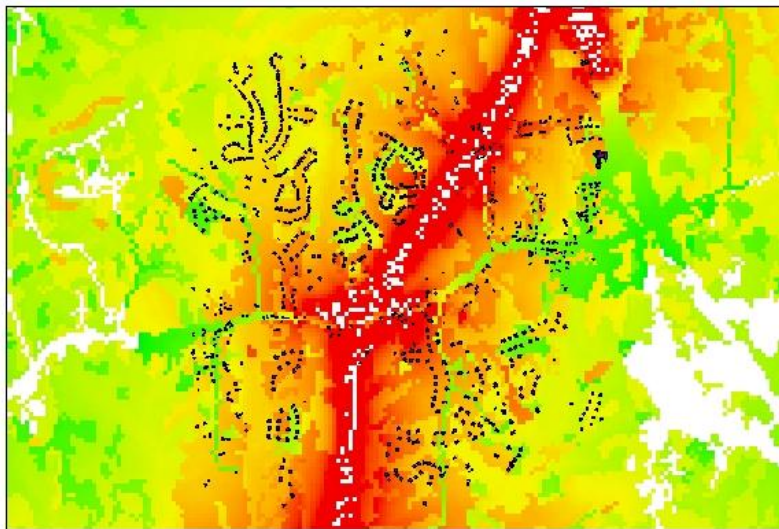


Figure 4.19. Study Area 3, Heavy Traffic

## **CHAPTER V**

### **CONCLUSION**

The model developed for this study predicts traffic volume noise in an area of future highway construction based on sound propagation and physical attributes which would affect sound levels. This model attempts to give an accurate prediction of traffic noise levels for the future Interstate 73 corridor through northwest Guilford County. As with any model, there are limitations to the predictive ability of this model and improvements which could be made. A further look at the results, along with possible improvements to the study and a discussion of assumptions which were made will be addressed in this chapter. However, despite these limitation and assumptions, it is clear from this study, that many residents and businesses will be affected by the traffic volume noise levels generated by this new interstate.

#### *Review of the Results*

The model developed in this research shows the potential impact of highway volume on noise levels in a region within a mile of future Interstate 73. The model captured the blueprint for the future interstate from its junction at North Carolina 68 to its junction at U.S. Highway 220. Landcover was categorized and was used to adjust sound levels from a baseline sound map based on the type of landcover. More dense landcover,

such as hardwood and coniferous forests subtracted from the expected sound level. Open areas, such as barren lands and water, subtracted little or no noise from the model.

Elevation data derived from a DEM was used to determine ridges and valleys. Areas which are low lying would reverberate noise and thus sound levels would increase. These areas slightly increase the sound levels in the model. Ridge areas slightly decreased the sound levels in the model.

The results of the model showed that even at the lowest levels of highway traffic, the sound level within 1/3 of a mile of the future interstate increased dramatically. As traffic volume increased, so did the area which showed a significant increase in sound level. For the daytime traffic model, the affected area increased to greater than 1/2 mile from the interstate. Areas affected by traffic noise in the heavy traffic model ranged from a mile to 1.25 miles.

Within the study area there were several areas which were dramatically affected by the noise caused by traffic. Three of these areas were studied and properties affected by the traffic noise saw decibel levels of greater than 60 decibels for the overnight model, 63 for the daytime model and 65 for the heavy traffic model. In each of these areas there were many properties, a majority residential, which showed a large increase in sound level. Overall, the results of this model showed that there is a significant impact from future highway traffic on the noise levels of properties within a mile of future Interstate 73.

### *Difficulties in Developing This Model*

Many studies have focused on developing models for predicting highway noise. A majority of these models are simply mathematical models for predicting how traffic affects sound levels. These models are applied to a specific point on a highway over a certain amount of time, often considering a single vehicle. These mathematical models are not developed initially for the prediction of noise from vehicle traffic over a large area while considering a large variety of vehicles.

While developing a GIS model, the mathematical models are useful in predicting source sound levels, as they consider how much noise is generated by certain types of vehicles. Also these models are useful in generating formulas that can be used to leverage the underlying architecture of a GIS as a way to predict how sound levels decrease over distance. However, these mathematical formulas are not developed to explicitly consider the influence of man-made features that can severely attenuate the propagation of noise.

In addition, these mathematical models often ignore physical features, such as elevation and landcover, which can also attenuate the propagation of noise. The usual mathematical model considers mainly distance and angle from the source and sometimes road type, thickness and width.

Another factor to consider with mathematical models is the variation in the data and derived formulas for predicting sound level often produce in dissimilar results. Each mathematical model varies slightly, even in variables and in function, making it difficult to decide which equation would work best in the GIS model. The GIS model would most

likely vary to one degree or another based on which mathematical model was used for both the sound source noise level as well as the formula used to calculate the noise level based on distance from the source.

Considering various GIS models result in a number of additional issues that need to be addressed. With the exception of the SPreAD-GIS model, every model that was found dealt with sound propagation in a densely urbanized environment. These models took into account factors such as how sound reflects off of buildings and thus urban “valleys” developed by rows of densely packed buildings. None of these models addressed the factors that were necessary to consider for the purpose of this research, mainly the effects of landcover and elevation on sound levels.

The research for the SpreAD-GIS tool is developed for a rural or wilderness application, and thus does consider these important factors. However, instead of giving details into the mathematics behind the SPreAD-GIS tool, most of the documentation deals with how the tool works. While acknowledging that landcover and elevation, as well as some other factors, impact the perceived sound level, there is no clear documentation as to how sound levels are impacted.

In developing this model, a weighted method was used both for landcover and elevation, to simulate the effect of these factors on the propagation of sound. In order to see if these factors were correctly weighted, a proposed project would be to develop this model for an existing highway and then using sound detecting equipment, validate the model. By doing this, the factors in the model could be better defined and a more accurate model could be developed. The largest hurdle in doing this research is taking

the time to set up sensors in a large number of locations with varying factors as far as distance from the highway, elevation and landcover, and to determine how to model each of these factors.

#### *Assumptions Concerning This Model*

In proposing a model for a highway which does not yet exist, it is necessary to predict a number of variables that will be used in the calculation of the model. One of the main assumptions that are made in this model is the traffic volume of the future Interstate 73 corridor through this area. Factors used to consider this model are given in chapter three. However, even considering these factors, the amount of traffic that will use this highway is, at best, an educated guess.

One of the main factors that could impact this model is the amount of traffic on the interstate. It is most likely that, at first, the amount of traffic on this section of Interstate 73 will be significantly lower than what the model predicts. There are several factors for this. First of all, since this section of Interstate will actually serve as a route around a busy section of Greensboro (Battleground Ave.), it is probable that much of the traffic on this interstate will not be local, but be long distance travelers. However, many travelers initially will not even realize that there is a new route available in this section of the city. This will cause travelers to continue to use alternate routes as they travel north to places such as Martinsville and Roanoke. Until this interstate starts appearing on road maps, atlases, GPS and websites, such as Google Maps, people will be less likely to use this route.



In addition, this route will be the first section of Interstate 73 completed between Greensboro and Roanoke. While it will bypass a significant section of Greensboro city traffic, it will continue to encounter small towns and at-grade intersections between Guilford County and Roanoke. Thus, many will choose not to use this route, opting instead for a slightly longer but less stressful freeway and Interstate routes.

A second assumption that is made is the mix of light and heavy vehicles along this future interstate route. For the daytime and heavy traffic models, a 33% heavy vehicle and 67% light vehicle mix was used, while for overnight traffic a 50/50 mix was used. If the ratio of heavy vehicles increases, so will the source noise level and thus the perceived noise levels along this study area. Likewise if the percentage of heavy vehicles is actually less, noise levels will decrease. These factors are very difficult to predict for a highway which does not yet exist.

One other factor that should be considered is the modifications to the natural environment that will be made by construction of the new interstate. This will affect the model in two ways. First of all, the elevation model will be changed. As the interstate is being built, there will be sections that will be graded level, whether by removing ground, and thus dropping the freeway into a “man made valley” or by raising the ground and thus placing the freeway on a “man made hill.” Any section of the interstate in which the ground is lowered is going to have a shielding affect which will decrease the impact of the traffic on the sound levels to the surrounding areas. Likewise, those sections that are raised up will have a tendency to propagate sound better.

Another factor in the construction of the roadway is the building of overpasses. Most of the local roads, which will cross the interstate, are going to be built as an overpass. This will create man made barriers as the land is built up for the approach to the bridge, and thus will block some of the sound in certain directions.

A final factor is that in the right of way of the interstate, any landcover will be removed. Areas of dense vegetation will be impacted and thus will allow the sound from the traffic to flow more freely, increasing sound levels in the immediate area.

#### *Impact of Highway Noise on Residents and Businesses*

To the average person, the question that probably would be most asked is how will this new Interstate affect me? There are some very definite conclusions which can be made, despite the fact that there are many unknowns that need to be answered before specific details can be verified.

The first conclusion that can be made is that many residents and businesses will be impacted by the noise generated from this interstate. The study area used to determine who would be affected was a one mile buffer around the proposed interstate route. From the results of the model, it was shown that everyone within this buffer would be affected to some degree or another by highway traffic noise. For those furthest from the interstate, the impact may only be a slight increase in noise levels, which may only be slightly irritating. However there will be many who live within a quarter mile or less from the Interstate who will be affected day and night by the noise generated.

Within the one mile buffer there are 5088 buildings and residential houses which could be affected by increased sound levels from the highway. Looking at a parcel map,

there are 4029 parcels which are within this one mile buffer. Parcels are not displayed in an effort to eliminate identification of individuals as well as to protect the privacy of those in this study area. Some of these parcels will be bought by the state for right-of-way for the new interstate, but most will not be purchased.

From the results of the traffic noise models, there are a few things that land owners within this area could do that would help to decrease the impact of the highway noise on their property. One of the greatest factors in decreasing highway noise is areas of hardwood forests. A long term solution to the problem of highway noise is to invest in planting trees, especially hardwoods along one's property. While this will not remove highway noise in all instances, it will have an impact on reducing the amount of noise experienced.

One additional thing that this study would recommend is to request noise barriers to be erected along the interstate route, especially in those areas greatly impacted by traffic noise. While the state is not required to do this, the results would be beneficial and would ultimately help the state, by minimizing the effect of traffic noise, which would reduce the loss in property value. This would then affect the tax base allowing the state to receive a larger amount in taxes.

Finally, this study would recommend homeowners especially to invest in sound proofing of their houses. This would be strongly recommended for those within a quarter mile of the proposed interstate. While this would not impact the overall traffic noise experienced on the property as a whole, this would make the home a sanctuary that homeowners could retreat to during hours of greatest traffic noise.

## REFERENCES

- Brown, A.L.; Affum, J.K. A GIS-Based Environmental Modelling System for Transportation Planners. *Computers, Environment and Urban Systems*. 26:577-590.
- Chung, E., Bhaskar, A., Kuwahara M. Large Area Noise Evaluation. *Highway and Urban Environment*. Springer Publishing, Netherlands. p. 579-589.
- DeKluijver, H.; Stoter, J. Noise Mapping and GIS: Optimising Quality, Accuracy and Efficiency of Noise Studies. *Inter.Noise 2000: The 29<sup>th</sup> International Congress and Exhibition on Noise Control Engineering*. Nice, France: August 27-30, 2000.
- El-Gohary, Mahmoud. Property Valuation Model: Effects of Traffic Noise on Property Value. ECE 557 Project, Portland, OR. December 2004.
- Golmohammadi, R.; Abbaspour, M.; Nassiri, P.; Mahjub, H. A Compact Model for Predicting Road Traffic Noise. *Iranian Journal of Environmental Health Science Engineering* 6(3):181-186.
- Li, Bengang; Tao, Shu; Dawson, R.W.; Cao, Jun; Lam, Kinche. A GIS Based Road Traffic Noise Prediction Model. *Applied Acoustics* 63:679-691.
- Metropolitan Planning Organization. Metropolitan Transportation Improvement Program FY 2009 – FY 2015. August 27, 2008.
- Pamanikabub, Pichai; Tansatcha, Marupong. Geographic Information System for Traffic Noise Analysis and Forecasting with the Appearance of Barriers. *Environmental Modelling & Software* 18:959-973.
- Pamanikabub, Pichai; Tansata, Marupong. Geoinformatic Prediction of Motorway Noise on Buildings in 3D GIS. *Transportation Research part D* 14:367-372.
- Piedmont Triad Rural Planning Organization, Piedmont Triad Council of Governments *Economic Atlas of North Carolina*, May 2011

- Reed, Sarah E.; Boggs, Jennifer L.; Mann, Jacob P. SPreAD-GIS: an ArcGIS Toolbox for Modeling the Propagation of Engine Noise in a Wildland Setting. Version 2.0. The Wilderness Society, San Francisco, CA.
- Steele, Cambell. A Critical Review of Some Traffic Noise Prediction Models. *Applied Acoustics* 62:271-287.
- Tansatcha, M.; Pamanikabud, P.; Brown, A.L.; Affum, J.K. Motorway Noise Modelling Based on Perpendicular Propagation Analysis of Traffic Noise. *Applied Acoustics* 66:1135-1150.
- Town of Summerfield. "Transportation projects." Town of Summerfield Planning Department. Accessed October 18, 2013.  
[http://www.summerfieldgov.com/index.asp?Type=B\\_BASIC&SEC={EB54A93B-CB13-43F3-BED9-4AE971DC7E8F}&DE={3011380D-7559-4A83-AF28-F9DDE1BEFFC5}](http://www.summerfieldgov.com/index.asp?Type=B_BASIC&SEC={EB54A93B-CB13-43F3-BED9-4AE971DC7E8F}&DE={3011380D-7559-4A83-AF28-F9DDE1BEFFC5})
- Weingroff, Richard F. Federal-Aid Highway Act of 1956: Creating the Interstate System. *Public Roads* 60(1). Acquired from  
[www.fhwa.dot.gov/publications/publicroads/96summer/p96su10.cfm](http://www.fhwa.dot.gov/publications/publicroads/96summer/p96su10.cfm)